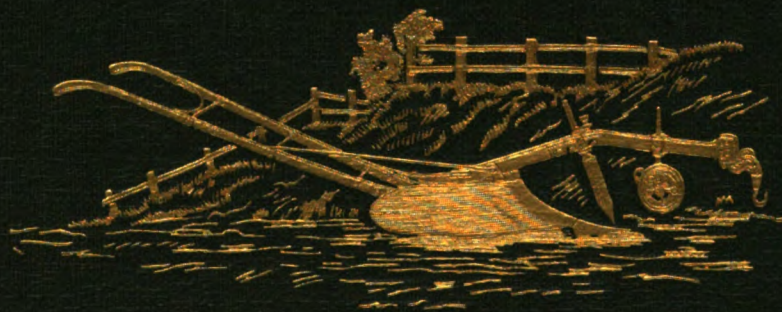


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FIFTH EDITION

REVISED AND LARGELY REWRITTEN BY

JAMES MACDONALD, F.R.S.E.

SECRETARY OF THE HIGHLAND AND AGRICULTURAL SOCIETY OF SCOTLAND

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'FOOD FROM THE FAR WEST,' 'POLLED CATTLE' AND 'HEREFORD CATTLE' (JOINTLY),
'SYSTEMS OF LAND TENURE,' ETC., ETC.

IN THREE VOLUMES

VOLUME I.—LAND AND ITS EQUIPMENT

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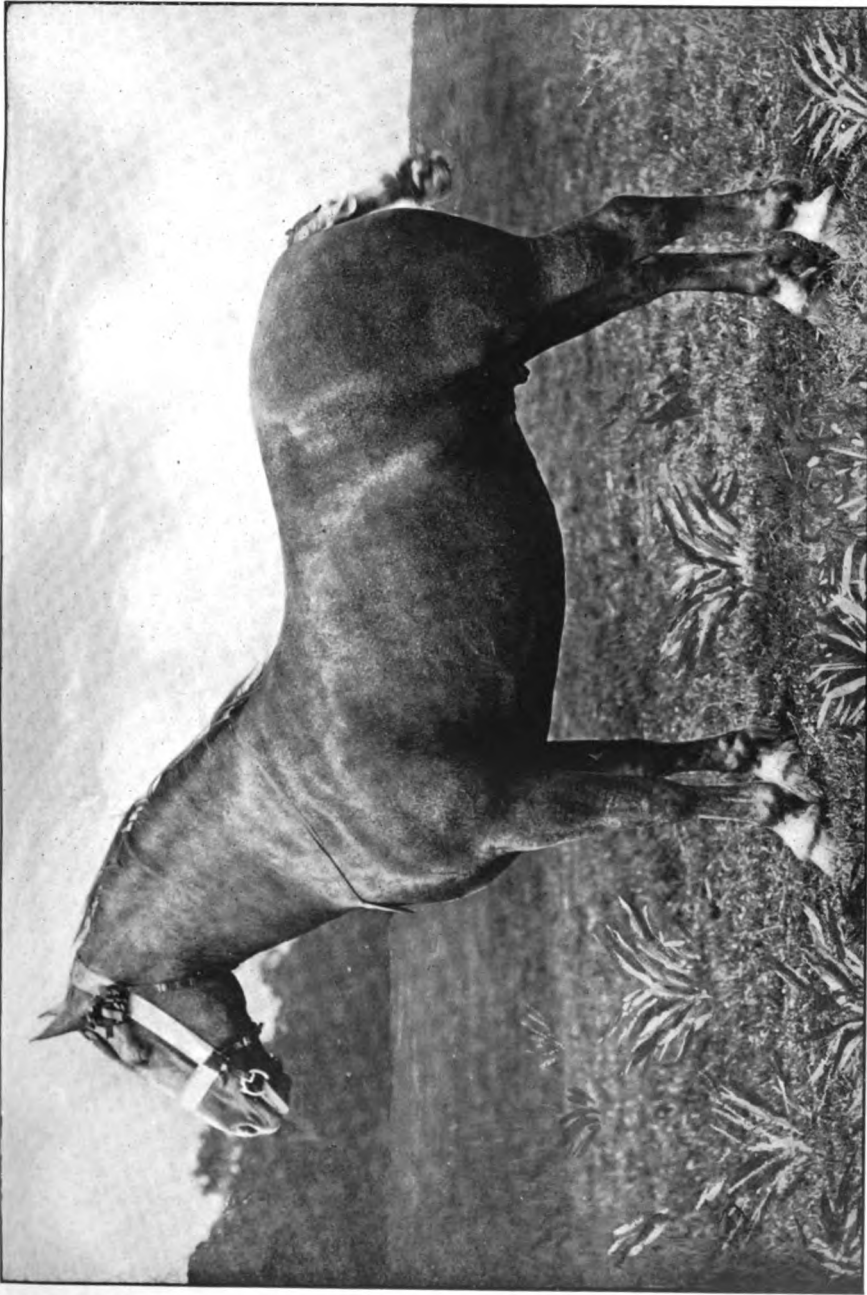
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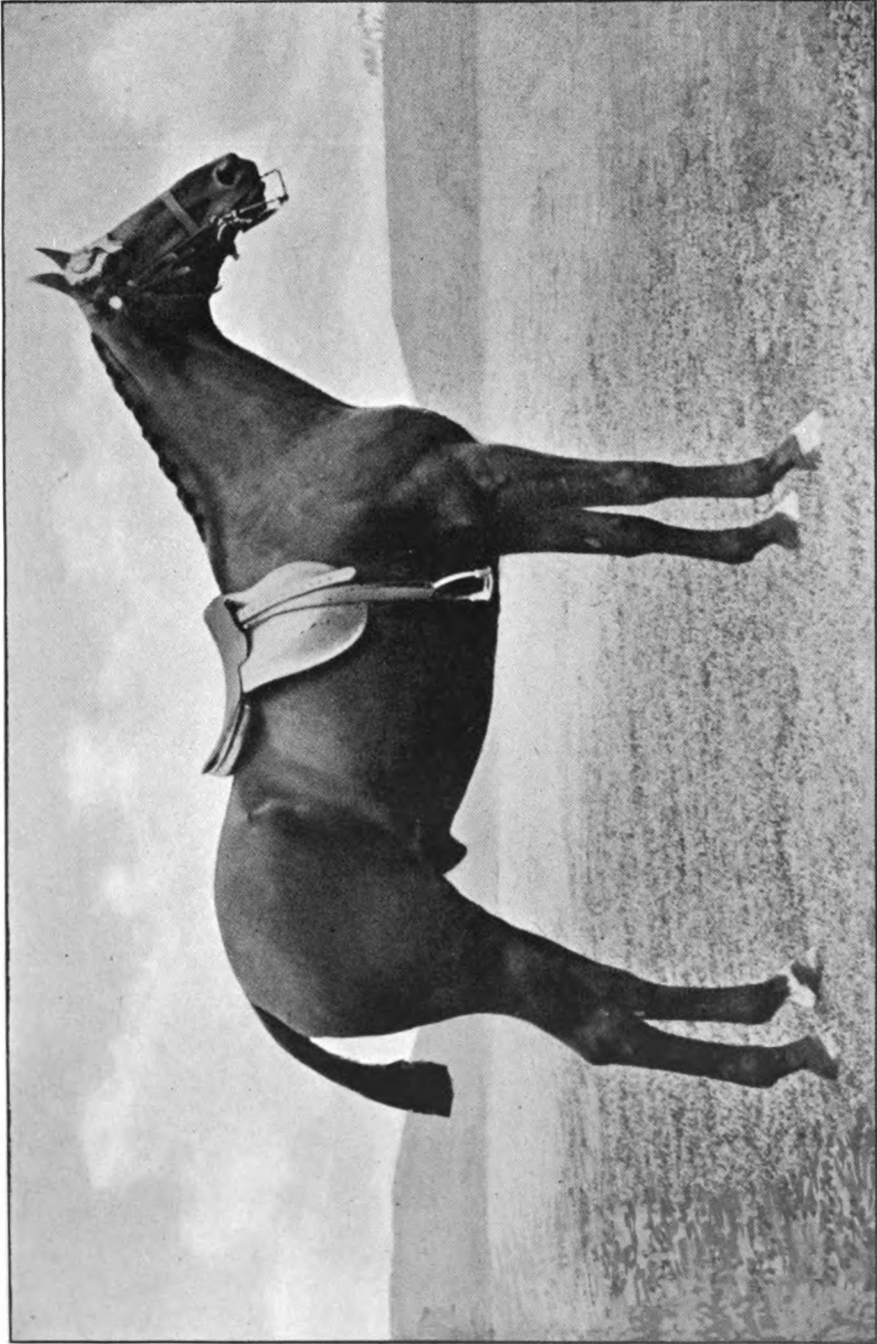
CLYDE DALE MARE, "PYRENE."

THE PROPERTY OF J. E. KERR, ESQ., HARVIESTOUN CASTLE, DOLLAR.



SUFFOLK WARE, "BOTTLE MAID," 4840.

THE PROPERTY OF R. E. WHITE, ESQ., BOULGE HALL, WOODBRIDGE.



STALLION, "WHEATLEY."

THE PROPERTY OF J. H. STOKES, ESQ., GREAT BOWDEN, MARKET HARBOUR.



HACKNEY STALLION, '66 COPMANTHORPE PERFORMER,' 9270.

THE PROPERTY OF ARTHUR HALL, ESQ., COPMANTHORPE, YORK.



SIOBTHORN COW, "SWETHEART."

THE PROPERTY OF LORD CALTHORPE, ELVETHAM PARK, WINCHESTER, HAMPSHIRE.



HEREFORD BULL, "CAMERONIAN," 23, 234.

THE PROPERTY OF CAPTAIN E. L. A. HEYGATE, BUCKLAND, LEOMINSTER.



DEVON BULL, '66 FOUND FINE 'UN, '550.

THE PROPERTY OF THE HON. E. W. B. PORTMAN, HESTERCOMBE, TAUNTON.

3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100

PLATE 39



GALLOWAY COW, "ALICE III. OF CASTLEMILK," 16,367.

THE PROPERTY OF SIR WILLIAM BUCHANAN-JARDINE, BART. OF CASTLEMILK, LOCKERBIE.

Univ. of
California

PLATE 51



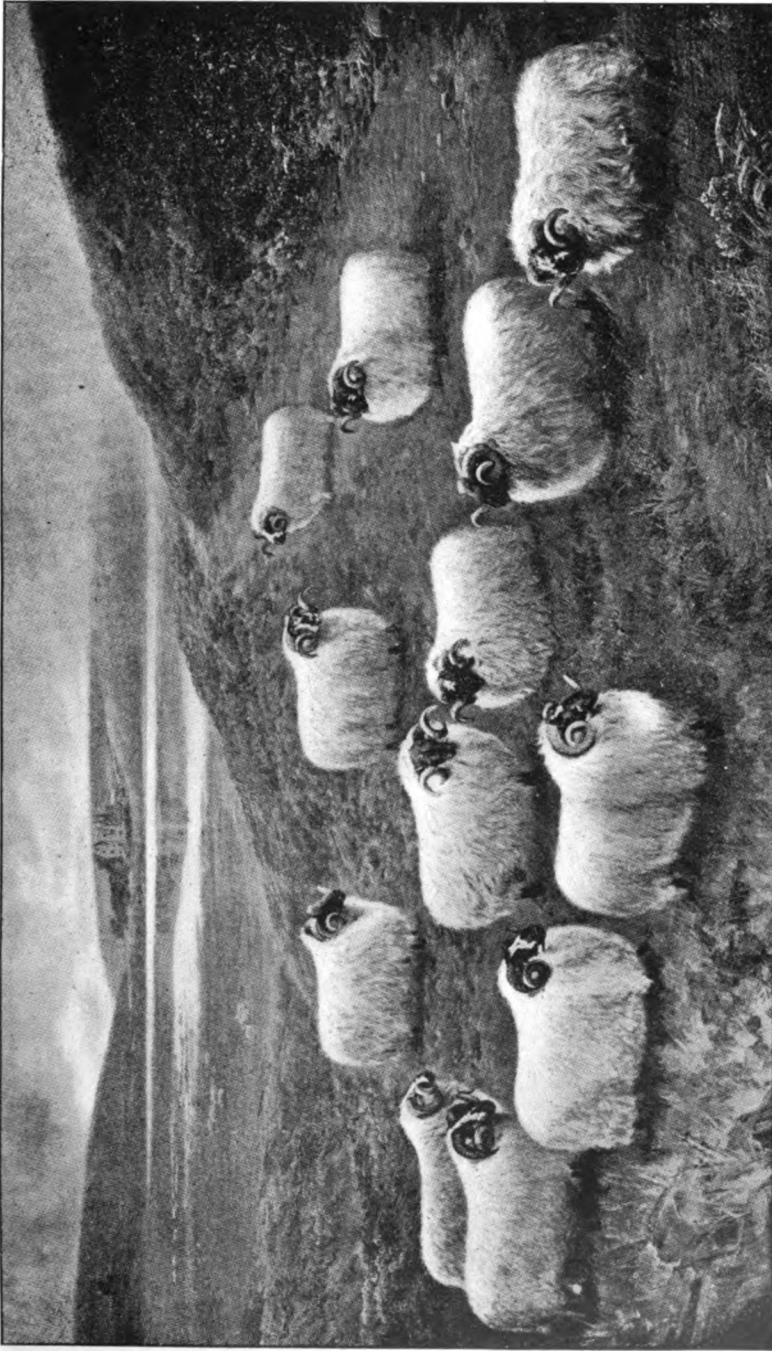
LINCOLN RAM.

THE PROPERTY OF F. MILLER, ESQ., CLIFTON ROAD, BIRKENHEAD.



COTSWOLD RAM.

THE PROPERTY OF MESSRS W. T. GARNE AND SON, ALDSWORTH, NORTHLEACH.



GROUP OF BLACKFACE RAMS.

BRED BY CHARLES HOWATSON, ESQ. OF GLENBUCK, AYRSHIRE.



CHEVIOT RAM.

THE PROPERTY OF JOHN ELLIOT, ESQ., HINDHOPE, JEDBURGH.



HALF-BRED RAM.

THE PROPERTY OF JAMES A. W. MEIN, ESQ. OF HUNTHILL, JEDBURGH.

RENTING AND ENTERING FARMS.

PHYSICAL GEOGRAPHY OF FARMS.

The young farmer's first consideration, in looking for a farm to rent or purchase on his own account, is what Virgil calls *The genius of the place*—

"The culture, clime, the winds, and changeful
skies,
And what each region bears, and what denies."

This calls for some enquiry into the physical geography of the farm: in particular, into those physical conditions which make up what is termed the correlation of soil and climate. In addition to this the young farmer will have to acquire a knowledge of subjects somewhat different from merely conducting a farm, and which are essential for him to know. These subjects are, to judge of land, to bargain for a lease, and to provide stocking for the farm. On taking possession of the farm, he may have more to do than these. He may have to enclose and drain the farm, and to erect buildings upon it. He should know the correct principles upon which the breeding and rearing of the domesticated animals are founded. These particulars may be as yet unknown to the young farmer, but he must become acquainted with them—

"In stated regions, from th' eternal cause:
Such Nature's compact and unbroken laws."

Diversity of Farms and Farming.—The farms of the United Kingdom occupy every available space of ground, from high up on mountains down to the sea-margin—the highest and the lowest level affording food for our domesticated animals. In such a diversity of level, the physical features of the farms must present diversified aspects, and farms occupying such diversified aspects must impose diverse modes of farming. Land at high altitudes cannot be farmed in the same manner as the land along the sea-margin. Accordingly there are many methods of farming, each of which, as shown in the introductory chapter, has its distinctive character.

VOL. I.

Conditions Regulating Rent.—The circumstances that affect the value of a farm are numerous. The land may have a steep inclination, and require increased labour to work it. The soil may be too strong or too loose, too wet or too dry. Its natural condition may be poor. The water-supply may be bad. The fences may be too numerous or too scanty, or in a state of dilapidation. The farm may be entirely exposed to the N. The surface of the fields may be irregular and abrupt. The farm may be exposed in an open country all round, or sheltered on all sides by natural or artificial objects. Coal and lime may be far off, or near at hand. The market town may be distant or near, and may or may not supply manure. The roads may be well placed and kept in good repair, and a railroad may be within easy reach or distant. The effect of all these particulars, individually and collectively, upon the money value of land, may not be easily determined; but that they, as well as the market price of produce, must have an effect in the value of a farm, is obvious to every one.

CLIMATE.

Climate is too little considered by farmers when they are on the outlook for a farm, and yet yearly experience teaches them that it has a marked effect upon their crops.

What constitutes Climate.—Distribution of heat over the globe mainly constitutes *climate*. General climate is measured from the equator to the polar circles in zones, which are classified into the torrid, temperate, and frigid—names indicative of different degrees of temperature.

Mean and Actual Temperatures.—Annual *mean* temperatures do not acquaint us with the climate which affects the products of the farm. Mean temperatures are derived from observations made on thermometers placed in the shade. But as our crops are not placed in the shade, and are exposed in the day

to the sun's light and heat, and at night to neither, what we desiderate, before we can determine the agricultural climate of any place, is results from thermometers placed amongst the crops and exposed in the open air to the weather day and night, summer and winter. We would thus be acquainted with the actual temperature of every month in the year during day and night.

A comparison of mean temperatures lets us know which of two places enjoys the greater heat on the average of days, or months, or years, but does not tell us the greatest and lowest degrees of heat at them in any season; and it is evidently the knowledge of these extremes that most interests us in the cultivation of our crops. We know that a given number of days, at a certain range of temperature, are necessary to bring a certain crop to perfection, while we also know that another range of temperature would destroy that crop; but the mean temperature could not tell us whether the crop should thrive or be destroyed.

Duration of Vegetation and Temperature.—"The duration of vegetation," wrote Boussingault, "appears to be in the inverse ratio of the mean temperature; so that if we multiply the number of days during which a given plant grows in different climates by the mean temperature of each, we obtain numbers that are nearly equal. The result is not only remarkable, in so far as it seems to indicate that upon every parallel of latitude, at all elevations above the level of the sea, the same plant receives in the course of its existence an equal quantity of heat, but it may find its direct application by enabling us to foresee the possibility of acclimating a vegetable in a country, the mean temperature of the several months of which is known."¹

In coming to this conclusion, Boussingault, we see, does not take the mean temperature of the year of any place, but that of the season in which the particular crop grows, and which, in truth, comprehends the whole temperature of the growing period of the crop.

Plant Growth and Temperature.—For each species of plant there is a particular temperature at which growth begins,

and below which it stops. It is not the same for all plants, but in temperate latitudes it is held that 42° F. is a sufficiently close approximation to the dividing line for cereals and most other agricultural plants. Botanic physicists have lately been endeavouring to ascertain accurately the amount of heat required for the growth of different plants until they attained maturity. Mr R. H. Curtis finds that 1961 day-degrees is the average required for the ripening of wheat. An examination of the records of wheat-sowing and harvest-time for the past 28 years disclosed that in 16 years there was no variation from this figure of 1961 exceeding 2 per cent, although the interval of time between sowing and harvest had differed by as much as seven weeks.

Temperature of Soil and Atmosphere.—The temperature of the ground has a close connection with that of the air immediately above it, and is mainly affected by the extent of the thermometrical variations in the superincumbent air in the course of the year. By the observations of the Meteorological Society of Scotland, made at 3, 12, 18, 22, 36, and 48 inches under the surface, a small increase of temperature is found below 3 inches. Below a limited distance the temperature ceases to be affected by the temperature of the general atmosphere, which is called the point of *invariable temperature*. In climes of great constancy this point will be found near the surface, and at the equator about the surface.

Snow and Soil Temperature.—From observations made at Katherinenburg it was found that at the depth of 14 inches the soil in January, when covered with a couple of feet of snow, was 10° F. warmer than at the surface. It is thus shown that in the bad conducting property of snow there is a remarkable protecting power in the economy of nature. However cold the air and the surface of the snow may be, if there is a considerable thickness of snow the temperature of the surface and underneath does not fall to freezing-point. Thus the snow is actually a warm covering to the vegetation; it is such a bad conductor of heat that the warmth of the earth cannot escape through it. In a climate

¹ Boussingault's *Rur. Econ.*, 647—Law's transl.

like that of Siberia the benefit of this is fully manifested. There the snow falls heavily at the beginning of winter, while the surface of the ground has not yet fallen below 32° F., the snow itself being at about that temperature, or, say, 30° F. The feathery crystals and the air they entangle are nearly absolute non-conductors of heat, and constitute the most effective of all possible covering. Thus the soil in such countries never falls to so low a minimum temperature as it necessarily reaches in this country, where we have a temperature of 15° to 20° F. over naked ground. Hence the paradox of Siberian vegetation, which is so luxuriant in the summer, when the heat of the long day is very intense. But though snow is a beneficent protector to the plant world in cold climates, it is chilling to the atmosphere. The radiation from the snow in a cloudless sky considerably lowers the temperature of the superincumbent air, and as the surface of the snow receives so little heat from the earth, the latter may be at a temperature above freezing when the snow surface is bitterly cold.

Drainage and Soil Temperature.—Drainage raises the temperature under the surface—that is, it permits the temperature of the atmosphere to penetrate deeper into the soil. It has been observed that the temperature of heavy soil was raised 15° by drains of $4\frac{1}{2}$ feet deep. And drainage not only permits the heat to penetrate deeper into the soil, but also enables the soil to retain it a longer time. It is no matter of wonder that drainage should effect this change in the soil. Over undrained land there is a constant evaporation of moisture, which is as constantly attended by a falling temperature. When the moisture is removed by drainage, the cause of the lower temperature is at the same time removed, and the temperature of the air rises.

Evaporation.—The evaporation of the water in the ground is caused in this way: Rain falls and penetrates the ground by gravity, and as it is gradually absorbed a succeeding rain descends, thrusting the first still lower, until an equilibrium of moisture is established from top to bottom of the ground. Whilst this is going on, the air takes

from the surface a portion of its humidity, and evaporation takes place. The upper layer, dried in consequence, draws moisture from that which is more moist beneath; and this moisture in its turn is also taken up by the atmosphere, and hence the source of constant cold over the surface.

Elevation and Temperature.—Another disturbing cause of the equable temperature on the surface of the earth is the inequality of surface into hill and dale. As we ascend a mountain the heat rapidly decreases, and it decreases more rapidly during the day than during the night, during summer than during winter, where the mountain is abrupt than where it rises in steps, and near the surface than at a distance from it.

Local Climate.—The characteristics of local climate engage the attention of the farmer more than the general climate of the country which he inhabits. Local climate may be defined to signify that peculiar condition of the atmosphere, in regard to heat, moisture, and wind, which prevails in any given place. The diversified character which it displays has been generally referred to the combined operation of several different causes, which are all, however, reducible to these two—*distance from the equator, and height above the level of the sea*; so that latitude and elevation form the great basis of the law of local climate; and the modifications of this law by other causes have generally but a partial and limited influence.

Elevation and Local Climate.—It is known that a slight difference of elevation in a mountainous district of this country, which has so high a parallel of latitude, may have a considerable influence on local climate; and that, other things remaining the same, one farm which is highly elevated has a greater chance of being affected by changes of climate than one on a lower level.

At sea-level we have the highest maximum fertility of soil in any latitude. But this only if the soil is of uniform composition and quality at sea-level and at higher altitudes in the same latitude. Otherwise the degree of fertility would correspond exactly with the contour lines of elevation, which it does not.

Other Conditions affecting Local

Climate.—Yet, independently of elevation, other local influences have a material effect in rendering the position of a farm less desirable; such as, vicinity to a lake or marsh, or a position at the foot of a hill or side of a large wood against which the wind generally blows—all which objects tend to lower the temperature below that of the country.

A position in a long narrow valley, or upon the haunch of a large isolated hill, or in a pass betwixt two mountains separating plains, is more subject to violent winds than the open country, the wind acquiring an accelerated velocity in such localities.

Desirable and Undesirable Situations.—An elevated table-land, being subject to a lower temperature and higher winds than a plain of the same extent on a lower level, is to be avoided.

The leeward side of a hill or large wood, or on flat ground backed with hills and woods to the N. and E., ensure a higher temperature and less wind than other parts of the country.

An extensive plain or valley, through which no large river passes, or in which no large lake or wood exists, is very little subject to violent winds.

In exposed situations the snow lies long, and the winds are keen; while in sheltered situations the snow soon melts, and the wind is gentle.

Variations of Local Climate.—These different circumstances produce a sensible effect on the local climate of a small country like Great Britain; and varied as it is in its physical geography, and surrounded on all sides by water, they have the effect of dividing the country into as many climates as there are varieties of surface and differences of position.

Such local influences, in most seasons, have a greater effect on the time of growth, quantity and quality of the produce of the earth, than the general climate of the country, although the general climate exercises a predominating influence in seasons of excessive heat or rain, and overcome all local influences, so as to stamp a general character over the season.

Local Climate and Land Value.—On looking at a farm, one should keep in mind these conditions of climate, an item of judging land which is often neglected by those who value farms, and

which is as often a cause of discontent to the tenant after he has found out its bad climate by dear-bought experience. In particular, careful attention should be given to both the normal temperature and normal rainfall of the district.

Rainfall and Crops.—The fall of rain in the vegetating season is an interesting and important factor—falling frequently being less favourable to vegetation than larger quantities at longer intervals; and a locality much affected by *vapour* renders the atmosphere in it more cloudy than desirable.

The water requirements of plants are enormous; but the need of water varies at different periods of growth, as well as for different plants. As a rule, it is most needed when the first leaves are appearing. It then diminishes till just before blossoming, when a large supply is called for; after which the crop ripens best with little or no more moisture.

J. T. Wills investigated the relation of the rainfall to the wheat produce per acre, in South Australia, for the six winter months, the growing season there, and found that for the seven best years there was a yield of 12.4 bushels of wheat with 18.5 inches of rain; for the next best years there were 10.0 bushels of wheat with 15.4 inches of rain; and for the six worst years there were 6.6 bushels of wheat with 13.5 inches of rain. The product of wheat in the first case was nearly twice as much as in last, with only a difference of 5 inches of rain.

The sugar-cane crops of the West Indies are similarly found to be proportional to the rainfall. Sir H. Rawson has given the result of fourteen years observations while he was Governor of Barbadoes, as follows:—

	Hogsheads Sugar.
1864-73 for each inch of rain	800
1874-77 " " "	900

In Jamaica, according to calculations made by Maxwell Hall, a rainfall of 79 inches in twelve months gave about 15 per cent more sugar per acre than a rainfall of 56 inches—an increased yield which would be equal to about £100,000 on the sugar crop of the colony.

Sheep-farming in Australia and Buenos Ayres, as J. T. Wills shows, is in the same way controlled by the rainfall.

Country.	Rainfall Inches.	Sheep per sq. mile.	Increased capacity for every inch of rain.
South Australia	8 to 10	8 to 9	1 sheep per sq. mile.
N. S. Wales (1)	13	96	22 " " "
N. S. Wales (2)	20	640	70 " " "
Buenos Ayres .	34	2630	140 " " "

It is thus seen that the relation between local climate and the growth of different crops is deserving of the most careful attention. What precise effect it has upon the money-value of land it is not easy to determine; but that land unfavourably situated as to local climate is of less value than that which is not affected by such local influences cannot admit of doubt.

JUDGING LAND.

Land valuers require wide experience and level heads, for it is by no means an easy matter to inspect a farm or area of land and accurately arrive at its value, so many and varied are the conditions and circumstances that have to be taken into account.

Examining a Known Farm.—When a farm is well known, the best season to inspect it is just before harvest, when the crop is in the fullest luxuriance and indicating its true condition.

Examining an Unknown Farm.—When a farm is unknown, the best season to look at it for the first time is in spring—March—in dry weather, after the largest proportion of the soil has been exposed by the plough, and when its actual state, in regard to dryness and wetness and condition, cannot be concealed. This is the season when the farm most fully exposes its varieties of soil—whether or not it requires drainage, whether any draining which has been done is still in good condition, and whether it is in a fair or poor condition as to fertility.

Local Knowledge necessary.—In judging a farm, the safest course for an intending offerer is to obtain the assistance of a friend experienced in farming, who is well acquainted with the part of the country in which it is situate, if such a one can be had. Indeed we regard local

knowledge as in all cases most essential. To judge strange land in a strange locality is most unsafe. There is much truth in the old saying that no man can judge land a hundred miles from home.

Etiquette of Farm-seeking.—It is considered amongst farmers a dishonourable act to look at a farm until it is in the market—that is, until it is known that the tenant is leaving it. It is considered bad behaviour to go over a tenant's farm, if he wants to keep it, even although it may be advertised.

Examining Soil and Subsoil.—On judging soil, the subsoil requires as much attention as the upper soil. Pits are dug through soil and subsoil in every field to ascertain their nature and texture, and whether they are similar or dissimilar in character. Most commonly they are dissimilar; because cultivation by the effects of manures, and the roots of growing plants, will have so changed the upper soil as to render it distinct from the subsoil, however similar they may have been originally.

A considerable variety of soil is to be looked for on every farm. The most uniform soils are diluvial deposits and peaty soils, the greatest diversity being presented between sandy and clay soils. Variety of soils is no objection to a farm, as it admits of differences in the rotations of cropping, and in conforming to the exigencies of particular seasons. A variety of soils, to be most convenient for a farm, should occupy separate fields apart from each other.

The characteristics and comparative fertility and agricultural value of the various soils will be so fully discussed under the section on Soils that little further on the subject need be said here.

Method of Soil Inspection.—All varieties of soil are judged of in the same manner. Every field must be walked over; and where a variety of

surface exists, the knolls and hollows must be traversed. On the knolls will be found the thinnest, and in the hollows the thickest, part of the soil. The spade thrust into the bottom of an open furrow will show at once whether the soil is thick or thin; and if thick in the furrow, it cannot fail to be so on the crown.

Character of Good and Bad Soils.

—It is not easy to describe in words the characters of a good or bad soil, or their state of fertility. It is only their physical characters that we can ascertain. Land to be judged requires to be in its ordinary workable state—not saturated with rain, not frozen, not burnt up with drought.

As a rule, clay soils feel hard under the foot; loams are softer; smooth deep soils feel as a thick carpet; thin soils as a thin carpet on a deal floor. Soils in high condition are friable; in poor condition are hard or too loose. The mark of the foot in soil in good condition is soon obliterated, by the elasticity of its particles; but in poor condition or tenacious clay, the footmark remains for a time impressed. In low condition, soils seem bleached by the weather, are much diversified in colour, appear to be in want of something, and are apt to be foul with weeds. Thin clays, hungry and deaf soils, are uncertain in character and yield.

Soils that have been drained, wrought, limed, and well farmed, and still indicate weakness, want of stamina, exhaustion, or a bleached appearance, may be concluded to be incapable of further improvement; but should they have been ill farmed, and yet indicate a natural strength, by good treatment they may yield fair crops in a few years.

Proportion of Good and Bad Soil.

—When a variety of soil is found on a farm, it should be observed whether they occupy different fields, which is a favourable allotment; for much variety in the same field is troublesome. The amount of the good and bad soils should be summed up separately, and seen which prevail. If the bad occupy only from one-fourth to one-third of the whole, the farm may be regarded a good one, and its character for excellence

will depend on the quality of its good soil; but should one-half of it be bad, the proportion is too great for the good soil to do justice to itself, and assist the bad; and where the proportion of bad increases beyond the one-half, the value of the good is reduced very rapidly.

Succeeding Good and Bad Farmers.

—Whether on good soil or bad, it is better to succeed an easy-going farmer than one who has pushed the land to the utmost. The former may have neglected and left the land foul, yet it may be improved; while the worst farmer to succeed is one who wears out his land, for no land is so difficult to restore as that which has been worn out. The fortunate chance is to succeed a farmer who has brought his farm into, and has kept it, and leaves it, in high condition as to fertility and thoroughly free from weeds.

Uncultivated Soil.—Part of the farm may be in an uncultivated state, which is not so objectionable as a worn-out farm. Its uncultivated soil will be fresh, and can be brought to bear sooner than worn-out land. The fresh portion, when brought in, would permit the older land to lie in grass to recruit and recover its tone.

Desirable Farms.—Desirable properties for a farm of mixed husbandry to possess are these: Extent not less than about 250 or 300 acres. Soil deep light clay-loam, capable of bearing turnips and wheat, incumbent on a naturally porous subsoil. A turnpike and a parish road crossing at its centre. Fields rectangular, and comprehending from 20 to 30 acres each. Fences of thorn-hedges. Surface gently sloping or undulating to the S. Elevation not exceeding 200 feet above the sea. Water from springs or rivulets accessible to every field. Steading situate near the crossing of the roads, capacious enough to contain all the cattle in winter, and convenient for every barn-work. Two or three paddocks of old grass near the steading for calves and other stock; and some good old grass for grazing cattle. Comfortable farmhouse and neat garden not far from the steading. Shelter by higher land or woods from the N., whence come cold winds and frost, and from the S.W.,

whence blow the strongest and most shaking winds. Market town of moderate size and near at hand. A railway station on the farm or within easy distance, where coal and lime and extraneous manures may be had. Distant from broad shallow lakes. Not among coal-fields, or near iron and chemical works.

It is barely possible for one farm to possess all these advantages, and it is not possible for every farm of a country to possess them all; but the more of these conditions that are conjoined the better for the farm. It is not easy to determine the difference in the money value arising from the presence or absence of all these conveniences, but it cannot fail to be considerable.

ESTIMATING RENT.

In estimating the rent that a certain farm may be worth, all varieties of soils cannot be valued on the same principle, since some produce chiefly grain, and others are devoted mainly to the support of live stock; but whatever be the products, the money value of every soil must depend upon its own capability.

Methods of Estimating Rent.—There are various methods by which the rent of arable land is estimated. Some arrive at it by taking the gross amount of corn the farm is capable of yielding, and the number of live stock it can dispose of in the course of a year, and deducting from the value of these at present market prices the expenses incidental to cultivation and the care and cost of stock, and a reasonable percentage on the capital to be invested, the remainder being the sum available for profit to the tenant and rent to the landlord.

The product is usually estimated according to the condition of the land at the time, and not what it may produce, or might have produced, by superior or inferior cultivation. If the farm is very dirty or reduced in condition, the rent may be fixed in accordance with what it may be estimated to produce in fair condition, and an allowance made for two or three years for putting into a proper state of fertility. This mode of estimat-

ing rent is applicable to carse farming, to town farms, to common farming, and to mixed husbandry.

The fixed money-rent of a pastoral farm is also estimated by the gross number of stock, whether of sheep or cattle, or of both, the farm can support in the course of a year, deducting the expenses attending the rearing of the stock, and a percentage on the capital invested in them.

Another mode of estimating rent is to pay so much money per head of the stock the farm will maintain.

The fixed money-rent of a dairy farm is also estimated by the gross amount of milk, butter, and cheese it will yield, and the live stock it will dispose of in the course of a year, deducting the expenses attending its management, and a percentage on the capital invested.

Another estimate of rent is to pay a sum for every cow the farm will support during the year—in which case the landlord has the farm in his own hands, and supplies the cows with food.

Term of Tenancy.—These estimates of fixed rent may be for a term of years or for a tenancy from year to year. Formerly the almost universal practice in Scotland as well as in the north of England, was to let farms upon leases of nineteen years' duration. This long term gave the tenant a feeling of security which he much appreciated. It enabled him to effect improvements upon his holding and recoup himself, or at least derive some benefit from them, before he could be disturbed in his tenancy. So long as prices of farm produce continued to rise or maintain a high and steady level, the nineteen years' lease was in much repute. It has been said with some degree of truth that it was the "making of Scottish farming." Unquestionably it served well its day and generation. A change was at hand, however. The tide of prices turned, and the depression which set in in 1879 deprived the nineteen years' lease of the place which it held in the affection of Scottish farmers. Obviously with falling prices a long lease is a disadvantage to the tenant.

Occasionally a Scottish farm is still let upon a nineteen years' lease, but shorter terms are now the rule. Leases of

fifteen or nineteen years, with mutual breaks at intervals of three or five years—by one or more years' previous notice in writing by either landowner or tenant—have become common in Scotland. In some cases the right to break at intervals is secured to the tenant only.

Yearly Tenancies.—The prevailing custom in the midland and southern counties of England is still a yearly tenancy, with twelve months' notice to quit from either party. This custom has also taken root in Scotland, and with the excellent provisions which are made in the Agricultural Holdings Acts for securing to the outgoing tenant compensation for unexhausted manures and improvements, the yearly tenancies will most likely grow in favour.

Tenure in Ireland.—In Ireland the old-established customs of tenure have been upset by legislation of various forms. The latest enactments have for their main object the transferring of the existing race of tenants into occupying owners, the price paid to the displaced owners being provided by the State on loans for long periods of years at low rates of interest.

Compensation for Disturbance.—The growing popularity of short tenures will be further influenced by another step taken by the Legislature on behalf of the tenant. We refer to the provisions in the Agricultural Holdings of 1906 for compensation to a tenant for being unreasonably put out of his farm by his landlord. Farmers should study these provisions carefully.

Produce-rent.—Were the value of farm-produce a fixed quantity, a fixed money-rent would undisputably be best for tenant and landlord. Prices, however, are liable to great fluctuation, and there has from time to time, especially in periods of depression, been much discussion as to the propriety of introducing some sort of "produce-rent,"—a rent equivalent to the current market value of so much of the produce of the farm—a rent regulated by a scale which would slide up and down with the fluctuations of prices.

In theory this system has much to commend it, but it is difficult to carry into practice. Indeed a thoroughly workable plan of determining produce-

rents has never yet been elaborated. The prices of grain have long been accurately ascertained and recorded, but it is not so with the prices of live stock and dead meat. And it is necessary for the perfect working of the system that the prices of the entire produce of each farm should be taken into account. Moreover, the fluctuations in the cost of manures, feeding stuffs, and labour, as well as the prices of produce, must be regarded; and with all these difficulties in the way, it is not surprising that in practice the system of produce-rents has made little headway.

Sliding Scale.—By the "sliding scale" system the plan adopted is to take the average price of produce at entry and the price current when a change in rental is desired, and upon the basis thus obtained calculate the fair rent. The following is an example for a farm of £500 rent at entry, worked in the fifth shift, the rent being allocated as under:—

	Price at time of entry.		Price at time of re-valuation.
	s. d.		s. d.
£200 on oats and barley	29 6	per qr.	20 0
£100 on hay	105	0 per ton	60 0
£100 on potatoes	95	0 "	40 0
£100 sheep and cattle	77	0 per cwt.	60 0

The new rent is worked out by simple proportion, as under:—

Oats and barley	29½	: 20 :: 200 =	£135 11 10
Hay	105	: 60 :: 100 =	57 2 10
Potatoes	95	: 40 :: 100 =	42 2 1
Sheep, &c.	77	: 60 :: 100 =	77 18 5

Rent in 1907	.	.	.	£312 15 2
Do. in 1875	.	.	.	500 0 0

Reduction necessary . . . £187 4 10

The once common custom of *grain-rent*—the value of a certain quantity of grain—was long ago proved unsound in principle, and has been abandoned.

Mixed Rents.—As a compromise between the fixed money and fluctuating grain rents, the plan of paying one half in a fixed money-rent and the other in the current market value of so much grain was at one time largely resorted to. The following is an example of the working of this system: A rent estimated at £1000 a-year. The average price of wheat, say 40s., barley 22s., and oats 16s. per quarter, their cumulative values

would be 78s. and average 26s.; and if 128 quarters of each sort of grain made up half the rent, the state of the rent would stand thus:—

The rent	:	:	:	:	:	£500	0	0	£1000	0	0
In cash	:	:	:	:	:	£500	0	0			
In grain—											
Wheat, 128 q ^{rs} . at 40s.						£256	0	0			
Barley, 128 "						228.	140	16	0		
Oats, 128 "						168.	102	8	0		
						3)78s.					
"						384	268.	499	4	0	500 0 0 999 4 0

In future no change would take place in the £500 paid in cash; but the £499, 4s. obtained from the prices of the year fixed the quantity of grain for that year at 128 quarters of each sort of grain, but which quantity would vary every year with the average prices. Or the conversion of the £500, half of £1000, into a grain equivalent may be done in this way: Suppose the £1000 a-year is 25s. for one acre, then 78s., the cumulative price of wheat, barley, and oats, : 8, the bushels in one quarter, : : 25s. : 2,564 bushels of each kind of grain, which, at their respective prices, give 24s. 11¾d. for one acre.

Interest, Profit, and Rent.—The rate of interest on money should enter as an element in the calculation of rent; and the rate of profit derivable from capital invested in a farm should be equal to that derivable from trade. A general rule is to reckon interest at 5 per cent, and the profit upon capital employed in farming should be at least 10 per cent.

Fixed Money-Rents.—The fixed money-rent is much more simple and workable than any sort of produce-rent, and practical men of mature experience rarely go far wrong in estimating what should be the rent of a farm well known to them. They estimate the amount of grain which the land will produce, and the quantity of stock it will support, in the condition they see it; and, calculating these at current prices, and having in view the cost of manures, feeding stuffs, and labour, they determine the rent which the farm can pay. While they estimate the rent in the existing condition of the farm, they judge whether it is capable of producing more by better farming, and this affords a latitude in the offer of rent to be made. Upon

this uncertain element of their opinion, rents are too often offered beyond the value of the land; and when bad seasons occur, or prices fall, or the tenant proves an indifferent farmer, the rent is soon found to be too high.

Advantages of a Fixed Money-rent.—Besides greater simplicity the fixed money-rent has, in the opinion of many farmers, several other points in its favour. A fixed rent gives the tenant a settled conviction in his mind what he has to pay and the landlord what he has to receive. To a tenant certainty is a stimulus to exertion; uncertainty sets his mind a-wandering after what may be unattainable, or at least prove speculative and unprofitable.

Rent and Land Value.—When calculated in the manner described, rent may be regarded as the *natural* value of the land. It is based on the supposition that the land is worth the sum at the time of the estimate. It also takes for granted that the farm is complete in all its appointments—the house, the stead-ing, the fences—and also that the land is in fair condition. It may also be regarded as a rack-rent—that is, the highest value the land can bear at the time. But when these appointments are incomplete—the house bad or wanting—the stead-ing incommodious—the fences dilapidated, or the land in wretched condition,—the rent must be modified to suit the particular state of the farm.

Deductions for Deficient Appointments and Bad Condition.—What proportion of the rent ought to be deducted for a bad farm-house, a bad stead-ing, bad fences, it is not easy to decide; but from 2s. 6d. to 5s. an acre may not be unreasonable. This, of course, varying with the length of the tenure. And for bad condition of the soil, from 5s. to 10s. an acre may not be too great a deduction, since it may require £5 or more per acre to put it into good condition.

"Covenanted" Rent.—The estimate of the deterioration by these exigencies, in the shape of pecuniary deductions, converts the rent into a *covenanted* one, and it assumes that same character when the tenant undertakes to build, or fence, or drain; but even when the landlord undertakes to supply these deficiencies, the rent is still a covenanted one, because

of the percentage paid over and above by the tenant, as the deficiencies are remedied; but whenever the deficiencies are supplied either by landlord or tenant, the rent, including the percentage, becomes the natural rent—that is, the true value of the farm.

OFFERING FOR A FARM.

The usual practice with candidates for a farm is to present to the landlord or his agent a written offer of the rent willing to be paid by them. Conditions accompany the offer when the buildings, land, or fences are out of order.

Ill-appointed Farms.—Farms are often presented in the market with the house in disrepair, the steading inadequate or incommodious, fences incomplete or neglected, and the roads in a bad state. No reasonable proprietor should expect a full rent for a farm in an incomplete state. If the buildings and fences are incomplete, it is but right either that the deficiencies should be provided or that the rent should be diminished as much as the interest of the money to be expended by the farmer to put the farm in order.

It is the true interest of every proprietor himself to put the farm-house, the buildings, fences, and roads in a habitable state, and to see that drains and fences are in good order, before exposing farms to be let, and not to trust to tenants doing such works in a substantial manner. An incoming tenant may possibly expect to find the *land* out of condition, and it is *his* duty to put that right; but the farm should be complete from the hands of the landlord, who will receive a rent in proportion to its state of completeness.

Essential Repairs.—The conditions in a lease may affect many subjects, but those which are indispensable are—the farm-house, which may require extensive repairs or additions to render it suitable to the nature of the farm—the steading may require additional accommodation for stock, which constitutes an important particular on most farms—the fences and drains may require completing, partial renewing, or extensive repairs—and the farm-roads may require to be put into a state serviceable for the farm.

These subjects demand careful attention at the commencement of a lease.

If the offer has been estimated irrespective of these particulars, it is but right that the tenant pay the interest on the sum expended by the landlord to put them right; but when the rent is estimated on the understanding that the farm was in a complete state, the landlord must put it into that condition.

This is the ordinary state of a complete farm, but other conditions may be requisite—such as the thorough drainage of some part of the land not hitherto efficiently drained; the formation of a large drain or outlet for the drainage, where such is necessary; the improvement of waste land; the substitution of one power to the threshing-machine for another—as steam or water for horse-power, when buildings have to be suitably changed.

Executing Permanent Improvements.—These constitute permanent improvements, and should be executed by the landlord; but the tenant may be willing to undertake a share in them, and along with the landlord have them satisfactorily executed. In almost every case the tenant executes the cartage of materials. When the tenant has capital to pay for such improvements himself, there is no reason why he should not arrange with the landowner to do so. To ensure his right to compensation on leaving the holding, the tenant should be careful to have the written consent of the landlord to execute any improvements other than those for which, according to the Agricultural Holdings Acts, the consent of the owner of the land is not essential.

It is a bad plan, however, for a tenant to cripple himself by expending on permanent improvements the capital which he would require for the proper working of the farm. These improvements should be executed by the landowner, leaving the tenant's capital free for his proper work of *farming* the land. Draining and improvement of waste land under a long lease often repay the tenant, just as he is repaid for the cost of mechanical power which saves the wear and tear of horses and harness.

Repaying Tenant for Cartages.—In cases where tenants have performed

cartages for buildings or other improvements, and may leave their farms before their leases have run their full terms, it sometimes happens that a portion of the costs of these cartages is repaid to the tenant by the proprietor. The proportion to be repaid varies with the period of the lease completed by the tenant. This, of course, is a matter which should be the subject of a specific agreement when the cartages are being arranged for.

Considering Offers.—Offers are often received by the proprietor from any number of candidates that may choose to offer for the farm. When all the candidates are on an equal footing, as regards capital, skill, and respectability, the one who expresses the fewest wants and offers the highest rent is usually accepted as tenant. It is not probable that all the candidates, or any two of them, are equal in capital, skill, and respectability; but the rule seems to be, *ceteris paribus*, the candidate who is willing to take the farm as it stands, and offers the highest rent, expects to be accepted.

Objections to "Offering" for Farms.—We have always been of opinion that the mode usually chosen by proprietors to present their farms to market is objectionable. The mode is this: When a farm is free for a new tenant, the circumstance is advertised in the newspapers. To this proceeding there can be no objection, since no better mode exists of giving publicity to the fact. In the advertisement is announced that *offers of rent* for the farm will be received until a certain day.

This is objectionable, inasmuch as it puts the farm up to *private* auction—one candidate being pitted against and bidding over others in the dark. In a *public* auction, competitors hear the bid-dings announced as they are made, and the successful competitor bids the highest price and gets the article. This is fair and above-board. In a private auction, no candidate knows the offers made by others, nor whether any or what conditions are annexed to them, nor how much the accepted offer is above the next highest.

Landowners "asking" Rent.—A more dignified and better course for a landed proprietor to pursue is to put a

rent on the farm, which he is sure any industrious and skilful tenant could fairly pay, and add such conditions of lease as will protect the farm from a greedy tenant, while affording ample liberty to the skill and judgment of a liberal tenant, and then invite farmers to become candidates, not as valuers of land, but as capitalists who can stock the farm, as farmers who can manage land skilfully, and as men who have respectable characters,—and from them select the one who has the most capital, the best skill, and the greatest respectability.

With the land valued in this way, instead of by the prevailing auctioneering system, we are persuaded that better farming would ensue, a more respectable class of tenants be established, rents be more easily and surely paid, and a greater cordiality promoted between landlord and tenant.

English Custom.—This system of the landowner or his agent deciding upon the rent to be accepted, and at once openly stating it to candidates for the farm, is extensively pursued in England, but very rarely in Scotland. On many English estates it is the custom to treat with each candidate as he makes application, informing him of the rent desired and the conditions of tenancy, considering his qualifications as a tenant, and accepting or declining his application before another candidate is admitted for actual negotiation. If the rent asked cannot be obtained in this way an "offer" may be received, and the rule on the best-managed estates is to accept or reject one offer before receiving another.

CONDITIONS OF LEASE.

It is most important that the applicant should consider with the utmost care every provision of the lease before making an offer for a farm. All uncertainties as to the conditions should be cleared up at the very outset, so that the offerer may not be in doubt as to his position under the lease if he should be the chosen tenant.

Adventurous Offerers.—Precautions are required between strangers—for there

are candidates for farms who are as unprincipled as to offer any amount of rent, and accept any conditions of lease, to get possession of a farm in good order; and on having reaped the first two or three crops, give much trouble to the landlord in demanding a reduction in the rent, or extensive repairs, or additions to buildings. Hence the utility of previously inquiring into the character of candidates, and selecting persons instead of accepting high offers of rent.

Care in Drafting Conditions.—Most farm leases we have seen are far too elaborate and too strict upon the tenants. Respectable tenants, who know their business, and desire to pursue it in a proper manner, do not need to be hemmed in on all sides by legal provisions. Yet while human nature is as it is, certain conditions of tenancy will be necessary in all bargains extending over a number of years. Conditions concocted by legal advisers for a whole estate are unsatisfactory, simply because they are not likely to be equally suitable for all farms. Each farm should have conditions suited to itself—to its soil, its situation, and state it is in; and then, although the conditions may be rather strict, a good farmer will accept them, knowing that restrictive conditions, like penal laws, are applicable only to offenders, or on proof that damage has been done.

The conditions of a lease are soon adjusted if both parties are desirous of meeting on fair terms. But in many cases, after the rent has been accepted, and the conditions unobjected to, the candidate afterwards proposes other conditions, which he thinks may mitigate the consciously high rent he has offered. In this manœuvre he often deceives himself.

Fair Conditions.—It is frequently found that conditions provided in leases are something like the following: Allowances for draining are stipulated for, and are a proper subject for negotiation when the farm requires it. The steadying may require more extensive repairs than the outgoing tenant was bound to make; certain additions and alterations may be considered necessary, and these should be detailed fully.

Although the outgoing tenant is bound to leave the fences in tenantable

repair, a new fence may be wanted across a field to divide it, or along the side of a wood or public road—and it should be kept in view that the "tenantable condition" in which the outgoing tenant has to leave fences, &c., is merely tenantable condition, less ordinary tear and wear or natural decay, so that the incoming tenant may not be justified in accepting from the landlord such fences, &c., as in a condition to last his lease. A farm-road is required for access to certain fields, which cannot be reached but by trespassing through other fields. An embankment is required along the side of a rivulet which occasionally overflows its banks and damages the crops of a haugh, or the lower parts of several fields. A watering-pool is required in some of the fields.

Most or all these changes, and probably others as well, may be desirable, and the lease should contain specific conditions as to their being carried out. It is a bad plan to first enter upon a lease of a farm and trust to being able afterwards to arrange for the execution of necessary or desired repairs and improvements.

Owner's Rights reserved.—In leases the landlord reserves for himself the right of opening quarries or mines, of making new roads, of entering into woods through fields, and of doing anything on the farm for the benefit of the estate, with the proviso of giving compensation to the tenant where his crop or land is injured. Cutting down woods sometimes does grievous harm to a farm by depriving some part of it of shelter, and in this case a reduction should be made in the rent.

Game Reservations.—Reservation may also be made for hunting and shooting game for the landlord and his friends. The question of damage by game has often caused heart-burnings between landlord and tenant; but most of this has been obviated by the Ground Game Acts.

Rent-day.—The dates at which rent is paid are specifically mentioned in the lease. Convenient times for the tenant are Candlemas and Lammas—February 2 and August 1. By February the farmer has had time to dispose of a great part

of his corn; and by August he has sold off his fat cattle, sheep, and wool. Both terms being intermediate between Whitsunday and Martinmas—May and November—when the half-year's wages of farm-servants, field-workers, and labourers become due, the farmer escapes large demands at one time. Still, in Scotland farm rents are generally due in May and November. In England rents are usually paid at Lady-day (March 25) and Michaelmas (September 29).

Stamping the Lease.—"A minute of lease, like missive letters, must be stamped before action will lie; and it is recommended that, before possession, a formal lease shall be executed."

Conditions of Cropping.

Injurious Restrictions.—It was at one time almost the invariable practice, and it is still the general rule, to tie down the tenant to certain courses of cropping by conditions in the lease or agreement of tenancy. Stringent conditions upon this point may be detrimental not only to the interests of the tenant but also of the landowner himself.

Restrictions may have been necessary when miscropping was the order of the day, and when neither rotation of crops nor manuring were properly understood or practised.

Now, however, with the great progress in the science and practice of manuring, the old-fashioned restrictions on cropping are entirely out of place.

Freedom of Cropping.—By perusal of the sections in this volume dealing with "The Fertility of the Soil" and "Manures and Manuring," it will be learned that, in so far as concerns the mere question of the fertility of the soil, the tenant, by making use of the facilities at his hand for manuring the soil, may with impunity grow what he pleases and sell what he pleases. Thus the landowner may with safety give his tenant practical freedom of cropping, qualified by the two conditions of keeping the land free from weeds and applying proper and adequate manure. Farmers should study the provisions of the Agricultural Holdings Acts regarding freedom of cropping and disposal of produce.

It is known with sufficient precision the quantities of the various elements of plant-food removed from the soil by the different crops. The fertility of the soil will therefore be guarded by conditions requiring the tenant to apply such manures at such times as will adequately and timely recoup the land for what he has taken from it.

Good Husbandry.—This is practically freedom of cropping, subject to the "rules of good husbandry." These rules, which are of course unwritten, may be somewhat variously construed. To experienced and intelligent farmers they are well enough understood. They may be read as being subject to a prescribed system of farming, or as meaning "good husbandry" in accordance with the prevailing customs of the particular district. In the absence of specific limitations the term may apply to every kind of husbandry, be it common or uncommon, which can be, or is, pursued without in any way, or to any extent, impairing the fertility or deteriorating the value of the holding. It is thus easy enough for practical men to determine when a tenant has overstepped the boundary-line of "good husbandry," within which the most enterprising tenant will have all the scope and freedom he can reasonably, or advantageously for himself or others, desire to have.

The practice of letting farms "with freedom of cropping, subject to the rules of good husbandry," is growing in favour, and has certainly much to commend it.

Reasonable Restrictions.—But, with every desire to allow reasonable freedom to the tenants, many landowners think it advantageous, in order to avoid differences, to lay down in plain words certain restrictions upon the system of cropping to be pursued. When the sole object of the landowner is to prevent the deterioration of his property, and not in any way to unduly limit the freedom of the tenant, it is easy to frame such conditions as will be satisfactory to all parties.

Adapting Conditions to Different Farms.—It is unquestionably desirable that such conditions of tenancy as are enforced should not be applied indiscriminately, but should be drawn up so as to suit each individual farm. Inat-

tention to this principle, and, adherence to stereotyped conditions, result in many a farm being ill farmed, as well as in disappointment and loss of capital to many a good farmer. Such conditions are usually found on estates where the factor is a lawyer or has little or no practical knowledge of farming, for an agent who has extensive practical knowledge of farming is well aware of the absurdity of such a system.

A weak soil cannot endure the cropping of a strong soil, nor a dull soil support stock like a sharp soil; each requires different treatment. Why, then, should they be placed under the same conditions? Similarity of conditions is a simple-looking mode of placing all the farms alike on an estate; but in the variety of farms, the similarity in conditions of lease or agreement evinces a want of judgment and discrimination on the part of the author of the conditions.

Let a good farmer exercise his skill according to the nature of the soil; and the improvement of the farm is the best proof that the system followed is the best for the farm. But, says an owner who takes a narrow view of the subject, liberty cannot be granted to one tenant without extending it to all; and in that view the skill of a superior tenant is cramped for the sake of maintaining a check upon an unskilful one.

Far better let the skilful tenant be encouraged, and the slovenly one kept under restrictions, by a thoroughly practical agent, than follow a generally depressing system.

The desirability of discriminating the capabilities of farms, and selecting the tenant for his skill and not mainly for high rent, is surely apparent.

Successive Corn Crops.—It is a common practice to introduce into leases or farm agreements a clause prohibiting the tenant from taking two corn crops in succession on the same land. If this condition be observed, land under tillage will not be very readily exhausted. Green crops or grasses and clovers would thus come between the corn crops; and it is well known that root crops cannot be grown profitably without the direct application of manure.

But while this is, as a rule, a safe measure, it may, if stringently enforced, oper-

ate injuriously upon the tenant. The clause should be amended to read that "two corn crops shall not be taken in succession upon the same land, unless the land receives at the time an adequate supply of appropriate manure." If the tenant apply to the land directly and immediately such a dressing of manure as will restore all the fertility the second corn crop withdraws, there is no good reason why he should be prevented from growing a second corn crop. Indeed, if he is sufficiently liberal and judicious with manure and careful as to tillage, he should not be restricted as to the number of corn crops taken in succession, for it is now well established that this is entirely a question of manuring, backed up by skilful and careful tillage.

The growing of two grain crops in succession has been encouraged by the larger area laid down to grass, and by the use of artificial foods. The decrease of arable land tends to curtail the supply of straw, and to make up for this some farmers often grow two grain crops in succession.

Disposal of Produce.—In many cases, tenants are prohibited from selling hay or straw to be removed from the farm. This is a remnant of an age and of a condition of matters that long ago ceased to exist. When the farm was entirely or mainly dependent upon the manure made from the consumption of its own produce, it was assuredly prudent to protect it from undue exhaustion by the removal of such raw material as hay and straw.

Now, however, that the supply of extraneous manure is both abundant and cheap, there is no longer any reason why a tenant should be prevented from selling any portion of the raw produce of his farm, if he should find it more profitable to do that than to consume it on the farm.

If any condition whatever is to be enforced as to the disposal of hay or straw, it should be qualified by a clause empowering the tenant to sell and cart away the produce, on the understanding that he brings on to the farm appropriate manure equivalent to the manurial value of the hay or straw removed.

Indeed, with a stipulation to this effect—that is, that any consequent manurial

loss shall be made up in purchased manures—the tenant should be allowed unfettered freedom as to the disposal of the produce of his farm.

Manuring.—It is probably right that, especially in the closing years of a tenancy, the landowner should have some check upon the tenant both in the applying and the withholding of manure.

It is well known that, by the application of an excessive quantity of such manure as nitrate of soda, a tenant may seriously impair the natural fertility of a soil. Such treatment would certainly not be in accordance with the rules of "good husbandry," and under that general condition the landowner would be entitled to redress.

Some think it better, however, to guard against the exhaustion of the soil by stimulating and one-sided manure, by providing in the conditions of tenancy that during the last three, four, or more years of the tenancy the dressings of manure shall conform to a certain standard, embracing in appropriate quantity and due proportion all essential manurial elements required to be applied to such soil.

With the right of compensation for unexhausted manures now secured to him, a condition to this effect, reasonably framed, should not inflict any improper hardship upon the tenant, while it would tend to maintain the natural fertility of the land.

Legal Provisions as to Freedom of Cropping and Disposal of Produce.—An important change in the position of tenants with regard to freedom of cropping and disposal of produce was brought about by the Agricultural Holdings Act, 1906. The provisions bearing on these questions give tenants a very large measure of freedom both in growing crops and in disposing of the produce, subject to reasonable conditions for safeguarding the interests of the owner of the land.

Leaving the Farm in Rotation.—An important and knotty point in farm and estate management is the question of the rotation in which the farm is to be left by an outgoing tenant. Even where absolute freedom of cropping is given to the tenant during his tenancy, it is customary to require him, in the event of his giving up the farm, to leave it in a

certain definite rotation, with so much of the land in grass of certain ages, so much set apart for green crop, and so much for corn crops.

What the particular rotation to be stipulated for may be will depend mainly upon the custom of the district and the kind of farming for which the farm and locality are best adapted. It is prudent to be guided in this matter by local custom, for, as a rule, it may be accepted as upon the whole the best. Yet upon estates under enlightened management, the rules as to "retiring rotation" are neither hard nor fast. If a tenant has shown that a certain farm can be worked to good advantage upon a system of cropping different from that prevailing in the district, different perhaps from that stipulated for in the conditions of tenancy, a prudent estate manager will not be so unreasonable as to grumble if the tenant should leave the farm in that rotation—that is, if the peculiar rotation is not of a kind that will injuriously affect the letting of the farm.

The object of the condition providing for the leaving of the farm in a certain rotation is perfectly sound and reasonable. Unless the farm is left with a fair proportion of grass, root, and corn land, the incoming tenant may be seriously handicapped and hampered in his initial efforts, while the letting value of the farm may be sensibly reduced.

This is one of the many points connected with estate management which demand the exercise of practical experience, mature judgment, and sound common-sense. Each individual case should be judged upon its merits. The letter of the law should be enforced only when necessary to protect the legitimate interests of the landowner. The universal, indiscriminate application of cast-iron, lawyer-made regulations to all sorts and conditions of farms and farmers cannot fail to be often the cause of unnecessary hardship upon tenants who deserve better treatment.

The Agricultural Holdings Act, 1906, has an important bearing upon this matter also.

Weed-cleaning.—On all well-managed estates emphatic conditions are laid down as to the destruction of weeds. Not a word can be said against the

stringent enforcement of these conditions. The suppression of weeds is as desirable in the interests of the tenant as for the sake of the landowner. Not only should the green crop break be thoroughly cleaned of weeds, but on the pasture-land, roadsides, and every odd corner, rag-weed, thistles, and other weeds should be timely cut down. By the accumulation of weeds many farms have been for years seriously reduced in value. Landowners are assuredly well entitled to protect themselves from losses arising in this way.

Pastoral Farms.—There being no rotation of cropping on a pastoral farm, except on the small portion of ground available for culture, the duration of the tenancy varies greater than with arable farms. As a rule, the leases on pastoral farms have never been so long as for arable farms, there being a mutual desire between landlords and tenants to adjust rents according to the prices of stock and wool every seven to fourteen years.

Penal Clauses.—Penal clauses are inserted into every lease and farm agreement, and seem fair for the protection of the landlord. In cases of miscropping—taking two corn crops in succession without purchasing the manurial equivalent—a penalty of £5 or £10 for one acre, over and above the rent, is provided, and may be exacted if damage is proved.

Removal.—An obligation is made imperative upon the tenant to remove from his farm at the time specified in the lease, without the exhibition of legal instruments of dismissal; otherwise the ejectment of a tenant reluctant to leave his farm might be attended with much trouble and considerable expense.

Subletting.—Subletting a lease to another party is usually prevented, as is also its assignation to trustees for behoof of creditors.

Feudal Customs.

In old leases still nominally, if not actually, in existence on some estates, there are found many trifling conditions indicative of the spirit of feudalism. One of these is the payment of *kain* or *cane* fowls, a custom long ago abolished. Personal services, as driving coals or cutting peats for the landlord's use, were also provided for. Drawing coal was a conve-

nience for a landlord who had no work-horses of his own, and was regarded as trivial by the tenants if demanded at a time when field-labour was not urgent.

Land Burdens.

In Scotland the public burdens on land are paid chiefly by the proprietor. In England the public burdens are usually paid by the tenants. Of the two methods, the Scottish is the fairer for both parties, it being no more than reasonable that the proprietor should pay the burdens of his own land.

When the tenant is not annoyed by the payment of public burdens, the landlord takes that into account on determining the rent, and so does a tenant when he offers for a farm. When burdens are paid by the tenant on stipulation, he does so for the convenience of the landlord, the payments being deducted from the rent. Some of the public burdens are paid partly by the tenant and partly by the landowner.

COMPENSATION FOR IMPROVEMENTS.

For many years an excited agitation was maintained for legislative recognition of the tenant's right to compensation for unexhausted improvements. The right claimed was, that when a tenant laid out money upon his landlord's land, which has obviously improved it, he shall have the power to make his landlord reimburse him the unexhausted amount when he leaves the farm. For example, if he laid out money in erecting buildings, forming fences, making farm-roads, draining, liming, manuring, and so forth, he shall be reimbursed for the unexhausted value of one and all of these improvements at the end of the lease.

It was at last generally conceded that the claim was a reasonable one, and Parliament has made it secure to all tenants in Great Britain by the Agricultural Holdings Acts. Farmers should make themselves familiar with these Acts, copies of which can be bought for a few pence. It is in particular important that farmers should note the provisions of these Acts as to the consent of the landowner being required for the execution of certain classes of improvements.

Record of Holding.

It has often been urged that, with the view of facilitating the adjusting of accounts between the owner and an outgoing tenant, a *Record of the Condition* of every holding should be made at the beginning of each tenancy. The preparing of such a record as this is provided for by the Agricultural Holdings Act, 1906.

ENTERING A FARM.

The times at which new tenants enter farms vary considerably in different parts of the country.

Scottish Custom.—The usual times of entry to farms in Scotland are at Whitsunday and Martinmas, or at the separation of the crop from the ground. These terms of entry are not equally favourable for the tenant in every kind of farming. In Scotland the Whitsunday term falls upon the 28th of May, and the Martinmas term upon the 28th of November.

Whitsunday Entry.—Entry to the houses and grass at Whitsunday is convenient for a tenant practising mixed husbandry, as it enables him to sow turnips for his stock in winter. Were he to enter wholly at the separation of the crop from the ground, he would have no turnips for his stock but what he purchased, either from the way-going tenant's crop on the farm or elsewhere. Complete entry cannot be given to any incoming tenant at Whitsunday, as he cannot enter the ground on which a crop belonging to the outgoing tenant is growing.

Martinmas Entry.—The entry at Martinmas enables the incomer to plough the stubble-land in time for the ensuing green crops. Entire entry at the separation of the crop from the ground is convenient for the tenant who breeds no live stock, as he can purchase them for winter, according to the opportunity afforded him to procure straw for litter and turnips for food, either from the way-going crop on the farm or elsewhere. Where the steelbow system is in force the incoming tenant, as will be shown presently, will always have at his hand a supply of straw in his first year.

The carse farmer, and he in the neigh-

bourhood of towns, would find this a convenient term of entry.

A dairy farmer finds it most convenient to enter at Whitsunday, having the grass in summer and turnips for winter; and so does the pastoral farmer, whether his stock be of cattle or sheep.

Convenient times for incoming tenants getting access to the different portions of holdings are, houses and land in grass at Whitsunday, land to be put under green crop at 1st February, and land under grain crop on the separation of that crop.

English Custom.—In England the times of entry vary much in the different counties. A common entry is at Lady-day (25th March) to the houses and grass, and to the rest of the land at Michaelmas (29th September). In some districts entry is given at Candlemas (2nd February).

Candlemas Entry.—With entry at Candlemas the new tenant lays down the entire crop of that year, and as the retiring tenant has already utilised the crop of the previous year, there is in this case no way-going crop to be dealt with.

Way-going Crops.—The way-going crop of grain (the property of the outgoing tenant) may be left with the incoming tenant, who may take it at mutual valuation (made by one valuator mutually chosen, or by two valuers and an oversman just before harvesting), or it may be sold privately or by auction to the highest bidder.

Steelbow.—Where the steelbow principle is in operation, the outgoing tenant must leave the straw on the farm. In other words, the grain but not the straw of the last crop belongs to him. "By a declaration that the straw and manure are steelbow, it is assumed that they are given by the landlord, and are to be returned to him; or, what is equivalent, delivered to the incoming tenant, to whom the landlord has conveyed his right to them. A sufficiency of manure, and of the materials for its formation, are thus permanently retained on the farm."¹

The steelbow is a great boon to the incoming tenant, it being equivalent to his possessing as much more capital, at the

¹ Hunter's *Law of Land and Ten.*, 264.

entry to his farm, as the straw and dung he receives are worth in money—for without it he would have to purchase both somewhere.

Selling Way-going Crop.—When the way-going crop is disposed of by public sale as it grows, the sale takes place a short time before the crop should be cut down. For the convenience of purchasers, the fields may be divided into lots comprehending two or more ridges, according to their length, each containing perhaps from 1 to 5 acres.

Disadvantage of the Selling System.—It is obvious that the incoming tenant has no more chance of securing a part or whole of the crop than any other person; and should it fetch higher prices than he is disposed to give, he will have to purchase straw elsewhere. The practical effect of this system upon the incoming tenant is, that he must possess capital to purchase as much straw as his stock will require in winter, and as much manure as will do justice to the land for the coming year.

Some leases provide that the outgoing tenant is obliged to offer one-half the crop on valuation to the incoming tenant, or the landlord—and should either refuse the offer, he is at liberty to sell it. In other cases, a private agreement is made for the whole crop between the incoming and outgoing tenants, irrespective of the lease or a sale. The purchaser bears the expense of cutting down and carrying away the part of the crop he has purchased.

In any case, the incoming tenant is placed in a worse position by this than by steelbow, which is a principle that might with advantage be adopted as regards straw and dung on all arable farms except those near towns.

Valuing Crops.—Between incoming and outgoing tenants the value of the crop as it stands depends on the price likely to be obtained for the grain in the market in the ensuing winter. The crops are estimated by the acre, and after deducting the expense of reaping, carrying, stacking, and threshing, the value per acre of the corn becomes known; and that of the straw is taken at so much per quarter of corn.

For example, the crop of wheat is estimated at 4 quarters per acre, and is worth

30s. per quarter; and the straw 14s. per quarter: the value of an acre will stand thus:—

4 qrs. wheat at 30s.	. . .	£6 0 0
Straw, 14s. per qr.	. . .	2 16 0
		£8 16 0
Harvesting and threshing, per acre, say		1 4 0
Value of the crop for 1 acre,		£7 12 0

The matter is adjusted in like manner with other sorts of grain. The value of oat-straw may be taken at from 10s. to 12s., and of barley-straw at 8s. per quarter.

Overlapping of Outgoing and Incoming Tenant.—Whenever the way-going crop is sold on its root, and it has been cut down and removed by the purchasers, the outgoing tenant takes his departure, and the incoming tenant enters and begins preparing the land for the crop of next season. But when the straw is held in steelbow by the farm, the outgoing tenant has a right to be accommodated in the stackyard and the steading until the crop is threshed and delivered, for which purpose he must have the use of the threshing-mill, and also accommodation for certain servants and horses required for the threshing and marketing the crop. This cumbersome arrangement is obviated when the incoming tenant agrees to take the grain at valuation.

It is provided in leases on many estates that, to save straw from waste, the outgoing tenant must not thresh his crop faster than the incoming one can consume the straw with his stock; and that the incoming tenant must not use the straw more slowly than will allow the outgoing tenant to clear the stackyard by the Whitsunday following.

Immediate Threshing.—A much simpler method is for the outgoing tenant to thresh out the entire crop as soon as it is ready for stacking. If the straw is carefully stacked, it will keep as well as in the unthreshed stacks, and the outgoing tenant can store or sell the grain at once as he may think best.

Not unfrequently the incoming tenant undertakes for the outgoing the threshing and delivering of the crop to market on payment for the trouble.

Fences and Houses.—There are always questions of minor magnitude, though of importance, to be settled between the landlord or incoming tenant and the outgoing tenant. These include the state of the fences, of the gates, of the steading, and of the dwelling-houses, all of which the outgoing tenant may be bound by his agreement to leave in tenantable repair—less ordinary tear and wear, in most, but not in all, cases.

The most common way of ascertaining the facts connected with these subjects is by *arbitration*. Hitherto the usual practice has been to have the arbitration undertaken by two competent and experienced men mutually chosen by the outgoing and incoming tenants, with power to the arbiters to appoint an oversman in case of a difference of opinion arising between them.

This system, however, has been to a large extent set aside in favour of the employment of a single arbiter, as provided by the Agricultural Holdings Act of 1906.

Repairs and Renewals.—On many of the best-managed properties the tenants' obligation in regard to houses and fences require them merely to execute trifling repairs, such as renewing a broken pane of glass, putting on a hinge on a door or gate, tightening wire, or mending a gate or door. If a house or a fence is so far decayed by tear and wear as to be untenable or unrepairable, the duty of renewing it devolves upon the landowner. This is as it should be. Properly speaking, it is no part of a tenant's duty to renew what has been exhausted by ordinary tear and wear.

Valuing Sheep Stocks.

In the majority of cases either the landlord or the incoming tenant is bound to take over the sheep stock from tenants leaving hill sheep farms.

The price to be paid is usually fixed in one of the three following methods. 1. Two arbiters visit and examine the stock as to quality at Whitsunday, and fix the price after the summer and autumn sales and markets have taken place. 2. The incoming and outgoing tenants choose an arbiter each, and these choose an oversman, who fix the price at

Whitsunday. 3. The incoming and outgoing tenants choose a mutual arbiter, who fixes the price at once at Whitsunday. This last is the simplest and least expensive plan.

In the case of two arbiters and an oversman being appointed, it very often happens that the oversman has most of the actual work to do, the two arbiters being inclined to act rather as advocates than as independent valuers.

It is maintained by sheep farmers that the single arbiter system should not be applied to hill sheep farms.

Excessive Valuations for Sheep.—There has been much discussion from time to time as to the excessive prices at which sheep stocks, especially in the Highlands of Scotland, are often valued over to incoming tenants. It is argued with much truth that a good stock of sheep is worth more to the man who is to continue them on their familiar pastures than they are on any other farm, and that an outgoing tenant, by being forced to dispose of his entire flock at a certain time in the open market, might sustain serious loss.

The amount of this "acclimatisation value," as it is called, might fairly enough be put at from 4s. to 8s., or in exceptional cases even a little more, per head, but in numerous instances in Highland counties sheep have been valued over to incoming tenants at sums exceeding the fair market price by thirty or more per cent. This mischievous custom has indeed gone so far in Scotland as to throw on sheep farms a burden akin to a tenant-right so heavy that few tenants have enough capital to face it. In the interests of both landlord and tenant it is highly desirable that this excessive valuation price should be put an end to, but on account of the large amount of capital involved the accomplishing of this is by no means easy. In some cases landlords are attaining this object by "buying up" the acclimatisation value—that is, by taking over the outgoing tenant's sheep at the valuation or "acclimatisation" price, and handing them on at "market price" to the new tenant, who is required to in turn pass the stock on to his successor at "market price," or at a price which shall include no sum anent acclimatisation value.

ADJUSTING FARM LABOUR.

The greatest difficulty which the young farmer experiences, on assuming the management of a farm, is in *distributing* and *adjusting* labour. To accomplish these correctly, both as regards the work and the labourer, a thorough knowledge is requisite of the quantity of work that can be performed in a given time by all the means of labour, animate and mechanical, which he possesses. It is the duty of the young farmer to acquire this knowledge with all correctness; for by a skilful *distribution* of the workers, the work can be performed in the most perfect manner in regard to time—with the smallest exertion as regards physical force—and with the best condition of the soil in regard to texture; and a judicious *adjustment* of workers to each other places every one in the position to perform his own share of the work with ease and comfort.

Good and Bad Management.—There are few things that strike a practical man more forcibly, in comparing the agriculture of different parts of the country, than the distribution of the work-people in the fields. In some parts, notably in England, it is not uncommon to see them employed in several fields of a farm at the same time, and the ploughs working scattered here and there. Now the great principle kept in view in the best farmed districts, as regards the work-people, is to concentrate the energies of all on particular pieces of work.

Many operations require the conjoint labour of the teams and field-workers, and when so employed they are confined within a given space of the same field, that the work may be performed in as short a time as practicable; and it is not possible to accomplish this end unless the labourers, of whatever kind, are so distributed and arranged that one party takes the lead and clears the way for another to follow and finish, and that not one individual shall flag in the work. When labourers are scattered over different fields, doing different sorts of work, no emulation exists, and no effectual superintendence can be exercised. The consequence is, that less work is done, and done not so well.

The manipulation of farm labour is

defective in most parts of Ireland, where the methodical arrangement of the labourers in the fields seems to be imperfectly understood.

INSURANCE AGAINST FIRE,
DISEASE, AND ACCIDENT.

It is short-sighted policy for a farmer to neglect the insurance of his furniture, his stock, and his crop against destruction by fire. He should insure his entire furniture, as the chances are that in the event of a fire taking place it would be consumed before the house is burned down.

The premium for insurance is now so moderate that no farmer should hesitate to provide himself with the comfort and safety which full insurance affords.

The tenant should covenant with the landlord for the payment of insurance on buildings—farm-house, steading, and servants' cottages—for they are the landlord's. The corn and live stock being his own, the tenant should pay for their insurance.

Live Stock and Fire.—Reference may be made here to a good mode of taking horses out of a stable when it is on fire. The horse is so timid an animal at the sight of fire that he will rather remain in the stable than venture out of it; but if the man who goes to take a horse out of a stable would strip off his coat, or take a sack or chaff-sheet, and throw it over the horse's head, so as to blindfold him, he will easily lead the horse out by the head. Cows may be treated in the same manner, when they are accustomed to be led; but it is doubtful if feeding cattle would submit as easily.

Fire-extinguishers.—Several patent "fire-extinguishers"—liquid enclosed in small bottles to be dashed upon the flame—are now sold, and are found to be of great service in checking a conflagration at the outset.

It is a good plan to have a "fire-hose" with water-pails at convenient points in the steading, so that in the event of fire breaking out something effective might be done to check it.

Insuring Crops.—Farmers may also insure their crops against loss incurred by *hail-storms*, but this is not done to any great extent. Sometimes hail does

material damage in England, especially to the proprietors of hothouses. In Scotland it is very seldom that serious loss is sustained from this cause.

Live Stock Insurance.—Excellent facilities are now afforded farmers for insuring their live stock, not only against fire, but also against loss by disease and

accident, as well as against foaling and calving risks. Several enterprising companies have devoted special attention to live stock insurance, and the terms offered to farmers are very moderate. He is a prudent farmer who amply insures himself against loss from fire, disease, and accident.

STOCKING FARMS.

The stocking of the different classes of holdings with animals, and machinery, implements, and other articles, varies greatly throughout the country. Even on similar farms in the same district there may be considerable variation, according to the resources and peculiar tastes of the tenants and other controlling circumstances. It would therefore be hopeless to attempt to draw up statements of stocking that would apply quite accurately to the general run of farms. Nevertheless, it may be of interest to submit the subjoined inventories of the stocking of certain typical farms.

STOCKING OF SCOTTISH FARMS.

There is given a detailed stocking for two typical South of Scotland farms, distinguished by the letters A and B. Each is taken at 500 acres in extent; Farm A, as consisting of good strong land, worth from 30s. to 40s. per acre of rent, and worked in a four or five shift rotation, for general cropping and feeding, a considerable extent being devoted to potato-growing. Farm B, with thin to medium land, worth a rent of from 15s. to 25s. per acre, is supposed to be worked on a five or six shift rotation, and devoted mainly to the rearing and feeding of cattle and sheep.

With regard to machinery and implements (the "dead stocking," as stocking other than live stock is sometimes designated), it may be explained that the prices quoted are such as are generally paid to makers and commission agents for new goods, and must be taken as only approximate prices, for the rates vary substantially.

Then it should be kept in view that on entering a farm a tenant seldom has to acquire a complete stock of new machines and other appliances. In almost all cases a considerable portion can be secured second-hand from the outgoing tenant or otherwise at prices much below first cost, and at good value too, if the buying is carried out with care and good judgment. In this way the capital outlay for the "dead stocking" at the time of entry may be lessened by 20 to 30 per cent or even more.

The stocking for the two Scottish farms, A and B, is adjusted on the assumption that the tenancies begin at the Whitsunday term, the new tenants getting entry to the houses and grasslands at that term, to the land for green crop at 1st March, and to the remainder of the land at the separation of the last crops belonging to the outgoing tenants. In some cases the entry to the land intended for green crop is obtained earlier than the beginning of March, to enable the new tenant to prepare the land for the crop. In other cases, entry to this break is not obtained till the Whitsunday term, and in this event the outgoing tenant performs certain of the tillage operations on the root-break, and is paid therefor by the incoming tenant.

With a tenancy beginning at the Whitsunday term, the grain crops of that year are sown by and belong to the outgoing tenant, and they are either taken over at valuation by the incoming tenant or sold when ready for harvesting. It is assumed that, in the case of farms A and B, the incoming tenants take the grain crops at valuation and perform the har-

vesting operations. The grass seeds to be sown with the outgoing tenant's last grain crop will be supplied by the incoming tenant, who pays the outgoing tenant for the sowing.

For a farm such as A there would be employed, say, 1 steward, 7 ploughmen, 1 cattleman, 1 stableman, and 2 labourers = 12 men at an average of 18s. per

week, with free house and garden; also about 8 other workers (boys, women, and old men) at an average of about 12s. per week, besides extra hands, thinning roots, in harvest, lifting potatoes, &c. A somewhat smaller force would suffice on farm B.

The following is a suggested stocking for these two typical Scottish farms:—

STOCKING OF TWO SCOTTISH FARMS.

STOCK, IMPLEMENTS, &c.	Farm A.		Farm B.	
	Arable farm of 500 acres, good strong land, rent 30s. to 40s. per acre, general cropping and feeding, 4 or 5 shift rotation.		Mixed farm of 500 acres, medium to thin land, rent 15s. to 25s. per acre, largely devoted to rearing sheep and cattle, 5 or 6 shift rotation.	
Work-horses,	14 at £50, =	£700 0 0	11 at £45, =	£495 0 0
Brood-mare and foal, . .	...			35 0 0
Harness-horse,		45 0 0		45 0 0
2-year old colt or filly, .	...			30 0 0
1-year old colt or filly, .	...			20 0 0
Young bulls,	...			25 0 0
(Crossbred) cows, . . .	5 at £16, =	80 0 0	15 at £16, =	240 0 0
Calves,	...		30 at £3, 10s. =	105 0 0
1-year old steers and heifers,	...		30 at £8, =	240 0 0
Ewes and lambs,	...		180 ewes (with 270 lambs) at 75s. =	675 0 0
Ewe and wedder hoggs, .	200 wedder hoggs at 38s. =	380 0 0	75 ewe hoggs at 45s. =	168 15 0
Tups,	...		4 at £12, =	48 0 0
Sows, boars, &c., . . .		10 0 0		10 0 0
Poultry,		5 0 0		5 0 0
Harness—sets,	7 sets at £12, =	84 0 0	5 at £12, =	60 0 0
Dog-cart,		35 0 0		35 0 0
Gig harness,		9 0 0		9 0 0
Riding-saddle, &c., . .		6 0 0		6 0 0
Short carts,	14 at £11, =	154 0 0	11 at £11, =	121 0 0
Hay and corn carts, without wheels,	10 at £5, =	50 0 0	9 at £5, =	45 0 0
Iron ploughs,	7 at £5, =	35 0 0	5 at £5, =	25 0 0
Chilled ploughs,	7 at 77s. 6d., say	27 0 0	5 at 77s. 6d. =	19 7 6
Slide for ploughs, . . .	7 at 12s., say	4 0 0	5 at 12s. =	3 0 0
Double-mould ploughs, .	3 at £4, 10s. =	13 10 0	3 at £4, 10s. =	13 10 0
Horse hoes,	3 at £2, 10s. =	7 10 0	2 at £2, 10s. =	5 0 0
Harrows—pairs,	7 at £3, =	21 0 0	5 at £3, =	15 0 0
Carriage for harrows, . .		3 0 0		3 0 0
Drag or "mumbler," ¹ . .		4 0 0		4 0 0
Swing-trees—set,	8 sets at 15s. =	6 0 0	6 sets at 15s. =	4 10 0
Drilling-trees,	3 at 2s. 6d. =	0 7 6	2 at 2s. 6d. =	0 5 0
Feering-poles,	6 at 1s. 3d. =	0 7 6	6 at 1s. 3d. =	0 7 6
Grass-seed harrows, . . .	1 set,	2 10 0		2 10 0
Cultivator,		10 0 0		10 0 0

¹ An implement for levelling or "rubbing" down clay clods.

Stock, IMPLEMENTS, &c.	Farm A. Arable farm of 500 acres, good strong land, rent 30s. to 40s. per acre, general cropping and feeding, 4 or 5 shift rotation.	Farm B. Mixed farm of 500 acres, medium to thin land, rent 15s. to 25s. per acre, largely devoted to rearing sheep and cattle, 5 or 6 shift rotation.
Roller, 2-horse,	 £6 0 0	
Roller, 1-horse,	4 at £5, = 20 0 0	4 at £5, = £20 0 0
Roller, notched drill,	 5 0 0	...
Wheelbarrow,	2 at 16s. 3d. = 1 12 6	2 at 16s. 3d. = 1 12 6
Broadcast, sowing,	 10 10 0	 10 10 0
Drill, sowing,	2 at £17, 10s. = 35 0 0	 17 10 0
Turnip, sowing,	2 at £5, = 10 0 0	2 at £5, = 10 0 0
Manure distributor,	 15 0 0	 15 0 0
Drill-disc-scarifier,	 7 5 0	 7 5 0
Graips, various,	13 at 2s. 6d. = 1 12 6	13 at 2s. 6d. = 1 12 6
Shovels, various,	10 at 4s. 6d. = 2 5 0	10 at 4s. 6d. = 2 5 0
Spades, various,	5 at 4s. 6d. = 1 2 6	5 at 4s. 6d. = 1 2 6
Dutch hoe,	 0 1 9	 0 1 9
Forks, various,	17 at 1s. 7d., say 1 7 0	17 at 1s. 7d., say 1 7 0
Hawks, various,	3 at 3s. = 0 9 0	3 at 3s. = 0 9 0
Mud-rake hoe,	2 at 2s. 3d. = 0 4 6	2 at 2s. 3d. = 0 4 6
Metal trough, pigs,	3 at 14s. = 2 2 0	3 at 14s. = 2 2 0
Hedge-knives,	3 at 3s. = 0 9 0	3 at 3s. = 0 9 0
Grindstone,	 2 15 0	 2 15 0
Axes,	2 at 5s. = 0 10 0	2 at 5s. = 0 10 0
Saws,	2 at 7s. 6d. = 0 15 0	2 at 7s. 6d. = 0 15 0
Sledge-hammer,	 0 5 0	 0 5 0
Hand and foot picks, {	3 at 4s. 9d. = 0 14 3	3 at 4s. 9d. = 0 14 3
	 0 8 0	 0 8 0
Stone-hammers,	 0 2 8	 0 2 8
Lever and wedges,	 0 15 0	 0 15 0
Tar-kits,	 0 5 0	 0 5 0
Oil-cans,	 0 5 0	 0 5 0
Cow bands,	7 at 1s. = 0 7 0	7 at 1s. = 0 7 0
Bull chain,	 0 2 0	 0 2 0
Bushel and strike,	 1 0 0	 1 0 0
Sowing sheets,	2 at 3s. = 0 6 0	2 at 3s. = 0 6 0
Pails,	10 at 2s. = 1 0 0	10 at 2s. = 1 0 0
Corn-sacks,	80 at 1s. 4d. = 5 6 8	80 at 1s. 4d. = 5 6 8
Horse-sheets,	2 at 15s. = 1 10 0	2 at 15s. = 1 10 0
Scythes,	3 at 6s. = 0 18 0	3 at 6s. = 0 18 0
Hand hay-rakes,	8 at 1s. 2d. = 0 9 4	8 at 1s. 2d. = 0 9 4
Horse hay-rakes,	2 at £8, 10s. = 17 0 0	 8 10 0
Swathe turn,	 15 0 0	...
Long ladders,	3 at 20s. = 3 0 0	3 at 20s. = 3 0 0
Half-long ladders,	3 at 12s. = 1 16 0	3 at 12s. = 1 16 0
Short ladders,	6 at 5s. = 1 10 0	6 at 5s. = 1 10 0
Wool-shears,	2 at 4s. 6d. = 0 9 0	3 at 4s. 6d. = 0 13 6
Beams and scales,	 2 10 0	 2 10 0
Buisting-iron and tar-pot,	at 3s. and 2s. = 0 5 0	at 3s. and 2s. = 0 5 0
Differential pulley-blocks and chains,	 2 0 0	 2 0 0

STOCK, IMPLEMENTS, &c.	Farm A. Arable farm of 500 acres, good strong land, rent 30s. to 40s. per acre, general cropping and feeding, 4 or 5 shift rotation.	Farm B. Mixed farm of 500 acres, medium to thin land, rent 15s. to 25s. per acre, largely devoted to rearing sheep and cattle, 5 or 6 shift rotation.
Potato-creels,	9 at 1s. 6d. = £0 13 6	...
Turnip-hoes,	15 at 1s. = 0 15 0	12 at 1s. = £0 12 0
Hooks for thistles,	15 at 2s. 6d. = 1 17 6	12 at 2s. 6d. = 1 10 0
Straw-rope twisters,	4 at 2s. = 0 8 0	4 at 2s. = 0 8 0
Combined mowing and reaping machine.	2 at £14, = 28 0 0	2 at £14, = 28 0 0
Stubble-rakes,	2 at £2, 10s. = 5 0 0	2 at £2, 10s. = 5 0 0
Hay-collectors,	2 at £1, 15s. = 3 10 0	...
Stack-covers,	3 at £3, = 9 0 0	2 at £3, = 6 0 0
Self-binding reaper and sheaf- carriers.	3 at £28, 10s. = 85 10 0	2 at £28, 10s. = 57 0 0
Cake-breaker,	 10 0 0	 10 0 0
Turnip-cutter,	 4 0 0	 4 0 0
Turnip-cutting cart,	 18 0 0	 18 0 0
Turnip-slicers,	2 at 15s. = 1 10 0	2 at 15s. = 1 10 0
Knives for turnips,	10 at 1s. = 0 10 0	10 at 1s. = 0 10 0
Sheep-boxes (turnips),	40 at 3s. 6d. = 7 0 0	20 at 3s. 6d. = 3 10 0
Sheep-boxes (corn),	40 at 1s. 6d. = 3 0 0	20 at 1s. 6d. = 1 10 0
Cattle-boxes,	15 at 2s. = 1 10 0	10 at 2s. = 1 0 0
Net-stakes,	300 at 20s. per 100 = 3 0 0	300 at 20s. per 100 = 3 0 0
Sheep-nets,	20 at 12s. = 12 0 0	20 at 12s. = 12 0 0
Mallet,	 0 3 3	 0 3 3
Drivers (piercers),	2 at 3s. = 0 6 0	2 at 3s. = 0 6 0
Hay-knife,	 0 4 3	 0 4 3
Chaff-cutter,	 15 0 0	 15 0 0
Hurricane lanterns,	10 at 3s. 6d. = 1 15 0	10 at 3s. 6d. = 1 15 0
Threshing-mill and finishing machine.	 150 0 0	 150 0 0
Oil-engine,	 115 0 0	 115 0 0
Fanners,	 8 0 0	 8 0 0
Corn-bruiser,	 9 0 0	 9 0 0
Steelyard and weights,	 4 10 0	 4 10 0
Sack-barrow on wheels,	 4 0 0	Simple barrow, 2 0 0
Grain-scoops,	4 at 2s. = 0 8 0	4 at 2s. = 0 8 0
Hoe for corn (wood),	 0 1 3	 0 1 3
Chaff-sheets,	 0 6 0	 0 6 0
Barn-brooms,	10 at 1s. 10d. = 0 18 4	10 at 1s. 10d. = 0 18 4
Corn-shovels,	2 at 4s. = 0 8 0	2 at 4s. = 0 8 0
Sack-needles and twine,	 0 2 8	 0 2 8
Milk-tins,	 0 12 0	 0 12 0
Turnip-pickers,	10 at 2s. = 1 0 0	10 at 2s. = 1 0 0
Harness polish and blacking,	say 2 0 0	say 2 0 0
Horse-brushes, curry-combs,	 2 0 0	 2 0 0
Corn-bins,	2 at 30s. = 3 0 0	2 at 30s. = 3 0 0
Lubricating oil and barrel,	40 at 2s. per gall. = 4 0 0	40 at 2s. per gall. = 4 0 0
Files,	} say 2 0 0	say 2 0 0
Binder sharpener,		say 2 0 0

STOCK, IMPLEMENTS, &c.	Farm A. Arable farm of 500 acres, good strong land, rent 30s. to 40s. per acre, general cropping and feeding, 4 or 5 shift rotation.	Farm B. Mixed farm of 500 acres, medium to thin land, rent 15s. to 25s. per acre, largely devoted to rearing sheep and cattle, 5 or 6 shift rotation.
Poultry-houses,	2 at £5, = £10 0 0	2 at £5, = £10 0 0
Potato-planter,	} say 25 0 0	...
Potato-digger,		
Potato-dresser,		
Hay-bogies,		
Rick-lifter,	2 at £6, 10s. = 13 0 0	...
Chain-harrows,	 8 10 0	...
Hay or straw baler,	2 at £4, = 8 0 0	 4 0 0
Cart grease,	 5 0 0	...
Basting-tub,	2 cwt. . . . 1 16 0	 0 18 0
Sheep-dipper,	 2 10 0	...
	...	 5 0 0
Total,	 £2467 4 5	 £3148 16 11
Deduct for saving by purchasing second-hand implements, &c., say	 200 4 5	 180 16 11
	£2267 0 0	£2968 0 0

In addition to these sums for "live" and "dead" stocking there would be other substantial outlays during the first year, and before the new tenants can have any stock or produce to dispose of. The chief of these items would be approximately as follows:—

	FARM A.	FARM B.
Labour,	£550	£450
Manures,	250	200
Seed for grass and green crop,	130	90
Feeding stuffs,	50	50
Corn and hay for horses,	330	250
Half-year's rent and taxes,	400	270
Household furnishing,	400	400
Various,	100	100
	£2210	£1810

These figures indicate that the outlays in the first year, before any income is obtainable, would amount to £4477 for farm A, and to £4778 for farm B.

Capital per Acre.

The capital thus represented per acre is about £9 for farm A and £9, 10s. for farm B. In some cases more capital would be required. There might be payments for the hay crop, and perhaps a smaller sum for second year's grass, while if the new tenant takes over the

corn crops, the use of capital would be required for a short time in paying for it.

In other instances for a farm such as A, considerably more money would be employed in buying in cattle and sheep and in purchasing cake and other concentrated foods. The number of live stock to be bought in the first year would largely depend upon the proportions of the green-crop break put under potatoes and turnips. On farm A it is assumed that potatoes would be grown pretty largely.

In many cases less capital than is above represented is found to be sufficient. The amount of working capital per acre which a tenant should have at his command on entering a farm will of course depend largely upon the character of the farm and the system of farming to be pursued. As has been seen in the case of farms A and B, less capital suffices for crop growing than for the rearing and feeding of stock, while some farms will carry a much larger number, as well as a more costly class of live stock, than others. Every farm, therefore, must be judged by itself in deciding as to the amount of capital it may require per acre. For good mixed husbandry farms from £8

to £10 per acre would suffice. Where the rearing and feeding of a costly class of stock and certain forms of dairy farming are predominating features, £12 per acre, and occasionally even more, might be profitably employed.

It will be observed that high prices are quoted for the sheep on farms A and B. For farms in more northern districts the sheep kept would represent less money by from 10 to 20 or more per cent.

STOCKING OF ENGLISH FARMS.

The figures in the appended statement represent the stocking of a typical farm in the county of Nottingham, distinguished by the letter C. Farm C is situated about four miles from a railway station, extends to 500 acres, of which 300 acres are arable, and the rest in pasture and permanent meadow. The rent is 17s. 6d. per acre, the soil a fairly strong clayey loam, but extremely healthy for sheep. The animals cannot be fat-

tened on the grass, being usually finished off in the yards in winter.

The prices stated for the "dead stock" (implements, machines, &c.) are approximately those for new goods, but here, as is mentioned in the case of the Scottish farms, a saving of 20 to 30 per cent or more could be effected by the judicious purchasing of second-hand machines, implements, &c., at sales in the neighbourhood. Michaelmas (29th September) is the time of entry to farm C.

For the working of such a farm as C a staff of about 12 to 13 men and boys would be required—1 horse-keeper at 17s. per week with free cottage, 1 stockman at 16s. per week and free cottage, 1 shepherd at 16s. per week with extra allowance per head for rearing lambs and shearing sheep, 5 or 6 labourers at 14s., 2 lads at 8s. or 9s., and 2 boys from 4s. to 6s. per week. Extra wages are usually paid in harvest and for overtime, while beer or beer-money is generally given for special work such as threshing, drilling, sowing manure, &c.

STOCKING OF AN ENGLISH FARM.

Farm C.		Farm C.	
Stock, Implements, &c.	Capital.	Stock, Implements, &c.	Capital.
Work-horses, 10 at £30, = £300 0 0		Binders, 2 at £30, = £60 0 0	
Harness-horse, 35 0 0		Reaper, 20 0 0	
Colts or fillies, 2 years old, 2 at £30, = 60 0 0		Mower, 14 0 0	
Yearlings, 2 at £22, = 44 0 0		Hay-tedder, 15 0 0	
Foals, 2 at £12, 10s. = 25 0 0		Swathe turner, 13 10 0	
3-year old steers, 20 at £14, 10s. = 290 0 0		Horse-rake, 11 10 0	
2-year old steers, 20 at £11, = 220 0 0		Elevator and gear, 50 0 0	
Cows, 2 at £16, = 32 0 0		Seed-drill for corn, clover, and turnip, 25 0 0	
Oxford-Down rams, 130 at 50s. = 325 0 0		Manure distributor, 15 0 0	
Shearling ewes, 70 at 55s. = 192 10 0		Crosskill roller, 13 10 0	
Lambs, 150 at 33s. = 247 10 0		Cambridge roller, 13 0 0	
Rams, 3 at £10, 10s. = 31 10 0		Flat-iron rollers, 2 at £9, 10s. = 19 0 0	
Swine, 60 0 0		Iron ploughs, 4 at £4, 10s. = 18 0 0	
Poultry, 15 0 0		Chilled ploughs, 4 at £4, 10s. = 18 0 0	
Oil-engine, 115 0 0		Double-furrow plough, 6 10 0	
Threshing-machine, 150 0 0		Double-mould board plough, 4 10 0	
Dog-cart, 30 0 0		Horse hoes, 2 at £4, = 8 0 0	
Waggons, 2 at £30, = 60 0 0		Cultivator, 9 0 0	
Scotch carts, with raves, 8 at £14, = 112 0 0		Set drag harrows, 8 0 0	
		Set chain harrows, 4 0 0	

Farm C.		Farm C.	
STOCK, IMPLEMENTS, &c.	CAPITAL.	STOCK, IMPLEMENTS, &c.	CAPITAL.
Sets harrows, 3 at £4,	= £12 0 0	Shovels, 10 at 4s.	= £2 0 0
Parmiter's weed harrows, 1 set, =	3 10 0	Spades, 6 at 3s. 6d.	= 1 1 0
Sets harness, 8 at £12,	= 96 0 0	Corn-shovels, 2 at 4s.	= 0 8 0
Gig harness,	8 10 0	Sets sway-trees, 6 at 15s.	= 4 10 0
Riding-saddle, bridle, &c. . .	6 0 0	Cow-ties, 12 at 1s.	= 0 12 0
Iron water-cart and pump, . .	14 0 0	Bushel,	0 10 0
Chaff-cutter, power,	15 0 0	Pails, 10 at 2s.	= 1 0 0
Winnowing machine,	9 0 0	Hedge-knives, 3 at 3s.	= 0 9 0
Weighing machine and weights,	5 0 0	Band-twisters, ¹ 3 at 2s.	= 0 6 0
Cake-breaker,	3 10 0	Corn-bin,	3 0 0
Root-pulpers, 3 at 66s. 8d.	= 10 0 0	Waggon and cart ropes, 12 at	
Turnip-knives, 6 at 1s.	= 0 6 0	3s. 9d.	= 2 5 0
Sheep-troughs, 40 at 5s.	= 10 0 0	Hen-coops, 6 at 6s. 8d.	= 2 0 0
Wooden sheep-racks, 4 at £3,	= 12 0 0	Brooms, 12 at 2s. 1d.	= 1 5 0
Cattle-boxes, 10 at 4s.	= 2 0 0	Waggon-jacks, 2 at 2s. 6d.	= 0 5 0
Wooden cribs for cattle, 6 at 20s.	= 6 0 0	Wicker-skips, ² 2 at 6s. 3d.	= 0 12 6
Long ladders, 3 at £1, 13s. 4d.	= 5 0 0	Hurdles, 48 at 10½d.	= 2 2 0
Six shorter ladders (assorted),	= 4 0 0	Hurricane lanterns, 3 at 5s.	= 0 15 0
Sack barrows, 2 at 15s.	= 1 10 0	Nosebags, 8 at 3s. 9d.	= 1 10 0
Pulley-blocks,	2 0 0	Shepherd's hut on wheels, .	12 0 0
Rick cloths, 3 at £3, 6s. 8d.	= 10 0 0	Light spring cart,	15 0 0
Waggon and cart sheets, . .	5 0 0	Small churn,	4 0 0
Pig-troughs,	2 2 0	Milk-pans, measures, &c., 4 at	
Grindstone,	2 0 0	6s. 3d.	= 1 5 0
Corn-sacks, 40 at 1s. 3d.	= 2 10 0	Butter-board, &c.	1 0 0
Wheelbarrows, 4 at 15s.	= 3 0 0	Sundries (including grease, tar,	
Hay-knives, 2 at 10s.	= 1 0 0	curry-combs, stable-brushes,	
Drag-rake,	0 14 0	whips, medicines, &c., say .	25 0 0
Hay-rakes, 12 at 10d.	= 0 10 0		
Scythes, 3 at 6s.	= 0 18 0	Total,	£3029 8 10
Sickle and knife-grinder, . .	1 0 0	Deduct for saving by pur-	
Hay-forks, 10 at 2s.	= 1 0 0	chasing second-hand im-	
Pitching-forks, 4 at 3s. 4d.	= 0 13 4	plements, &c., say	230 8 10
Dung-forks, 6 at 3s. 4d.	= 1 0 0		£2799 0 0

¹ For making ropes of straw.² A sort of basket for carrying chaff.

With entry at Michaelmas the tenant of farm C, in addition to the foregoing sum of about £2800, would have to make something like the following payments out of capital in his first year:—

FARM C.	
Manual labour,	£500
Artificial manures,	75
Seeds (corn, grass, roots, &c.), .	200
Horse corn and other foods, . .	350
Tenant right (including hay and straw taken over),	600
Half year's rent and whole year's rates,	270
Household furnishings, say . . .	400
	£2395

In the case of farm C the total amount of capital represented is thus £5200, equal to about £10, 8s. per acre.

Upon English farms, which are either wholly or mainly grazing, there is great variety in both the "live" and "dead" stocking. On a 500-acre grazing farm in Buckinghamshire, with only 25 acres under tillage, and the rental 22s. 6d. per acre, the normal head of live stock consist of about 270 cattle, 370 ewes and shearlings, 300 lambs, 12 work-horses, and 4 riding- and driving-horses, no pigs being kept.

On the better class of English dairy farms a large number of live stock are kept. On a dairy farm in Buckinghamshire, extending to 364 acres in grass and 136 arable, rented at 23s. per acre, the live stock usually comprise 62 cows in milk, 22 cows in calf, 62 heifers (some of them in calf), 42 calves and stirks, 4 bulls—in all, 192 cattle; 140 ewes, 102 culled ewes, 30 shearling ewes, 120 lambs, 6 rams—in all, 406 sheep; 10 work-horses, 10 nag horses and 20 colts, including hunters kept for breeding purposes—in all, 40 horses;

6 sows and 12 young pigs—total live stock, 656 head.

STOCKING SCOTTISH DAIRY FARMS.

The stocking of dairy farms varies as greatly as the stocking of other classes of farms. A typical Scottish Dairy Farm of, say, 150 acres, good average land rented about 20s. per acre, would be well stocked with the following, the entry being at Martinmas:—

LIVE STOCK FOR 150 ACRE DAIRY FARM.

4 Work-horses at £30, . . .	£120	0	0
1 Driving horse, . . .	25	0	0
5 Sets of horse harness, . . .	40	0	0
45 Cows at £13, . . .	585	0	0
10 Six-quarter heifers at £8, 10s. . .	85	0	0
2 Brood sows at £5, 10s. . .	11	0	0
100 Head of poultry at 2s. . .	10	0	0
20 Breeding ewes at £2, 5s. . .	45	0	0
	<u>£921</u>	0	0

FARM IMPLEMENTS.

3 Farm carts at £12, £36 . . .	£36	0	0
1 Dairy spring van, . . .	25	0	0
1 Dog-cart, . . .	28	0	0
3 Ploughs, 2 general-purpose and 1 double-moulded with whippetrees, at £4, 15s. . .	14	5	0
3 Brake of harrows at £3, . . .	9	0	0
1 Cultivator, . . .	9	10	0
1 Turnip-sowing machine, . . .	5	0	0
1 Roller, . . .	5	10	0
1 Reaper and binder, . . .	36	10	0
1 Mower, . . .	15	10	0
1 Horse-rake, . . .	8	0	0
1 Hay-collector, . . .	1	12	0
1 Wheelbarrow, . . .	0	12	0
1 Meat-barrow, . . .	3	7	6
6 Graips, 3 shovels, 1 spade, . . .	0	17	6
6 Forks, 3 hand-rakes, 6 hoes, . . .	0	18	0
1 Hammer, 1 cross-cut saw, . . .	0	7	6
2 Bass brooms, . . .	0	4	0
2 Drill harrows at 27s. 6d. each, . . .	2	15	0
	<u>202</u>	19	0

THRESHING MILL AND BARN UTENSILS.

Threshing mill taken over at valuation at, say, . . .	£60	0	0
1 Set of winnowers, . . .	6	10	0
1 Bushel measure, 2 pans, 4 riddles, . . .	3	10	0
	<u>£70</u>	0	0

CROP TO BE TAKEN OVER.

For Martinmas, 40 acres of white and green crop at, say, £7 per acre, . . .	£280	0	0
Dung on the farm at valuation, . . .	20	0	0
	<u>£300</u>	0	0

DAIRY OUTFIT FOR THE SWEET-MILK TRADE ON A 150-ACRE FARM.

1 Vertical boiler, 6 ft. by 2 ft. 6 in. . .	£28	0	0
1 Steaming block and all the steam tubing for carrying steam to tank, &c.	4	5	0
1 Hot-water tank fitted with steam and tap, . . .	3	0	0
1 Washing-tank and plug,	3	10	0
1 Milk-cooler complete,	6	10	0
6 Milking-pails and 2 carrying pitchers, . . .	1	16	0
2 Strainers,	0	9	0
30 Railway milk-cans at 21s.	31	10	0
1 Milk-tester,	6	15	0
1 Milk-recorder complete,	2	2	6
	<u>£87</u>	17	6
Total,	<u>£1581</u>	16	6

This amounts to about £10, 10s. per acre, but by purchasing implements and other "dead stock" at auction sales the necessary capital might be kept down to £10 per acre.

If the farm were devoted to cheese-making or butter-making instead of the selling of sweet milk the dairy appliances would be somewhat more costly, as is indicated below:—

CHEESE-MAKING OUTFIT FOR A FARM OF 150 ACRES.	
1 Vertical boiler, 6 ft. by 2 ft. 6 in.	£28 0 0
1 Steaming block and all the steam tubing for carrying steam to tank, &c.	4 5 0
1 Hot-water and 1 washing tank,	6 10 0
8 Pails and 2 strainers,	2 5 0
1 200-gallon cheese vat,	14 10 0
1 Double cheese press,	6 15 0
10 Chissets, with followers, &c., at 20s.	10 0 0
1 Pair curd knives and curd shovel,	2 0 0
Cheese racks, self-turning,	12 0 0
1 Milk-tester,	6 15 0
1 Milk-recorder,	2 2 6
	<u>£95 2 6</u>

BUTTER-MAKING OUTFIT FOR A FARM OF 150 ACRES.	
1 Vertical boiler, 6 ft. by 2 ft. 6 in.	£28 0 0
All the necessary steam fitting carrying the steam throughout,	4 5 0
1 Hot-water and 1 washing tank,	6 10 0
8 Pails and 2 strainers,	2 5 0
1 Steam turbine separator com- plete,	33 0 0
1 Milk and cream cooler,	6 10 0
1 Butter worker,	2 7 6
1 Cream-ripening vat,	4 15 0
1 Butter-tub, 1 butter-board,	0 9 0
1 Pair Scotch hands, 1 ther- mometer,	0 3 6
1 Gerber tester,	6 15 0
1 Dairy herd recorder,	2 2 6
1 Over-end churn,	6 10 0
	<u>£103 12 6</u>

FARM-SERVANTS AND WAGES.

The labour of the farm is an important element in agricultural economy. Its cost has advanced from 30 to 50 per cent, in some parts even more, since 1850, and in other respects the condition of the farm-labourers in the British Isles has been greatly ameliorated. They not only receive higher wages, but they are also provided with more comfortable dwellings, are better treated in regard to food, and have shorter and more regular hours of labour.

Methods of Hiring.

The methods and times of hiring and terms of engagements vary greatly throughout the country. Generally speaking, half-yearly or yearly engagements prevail in Scotland, with wages paid in one sum at the end of the term, or in instalments as arranged. In England and Ireland the terms are shorter and less regular, wages being as a rule payable weekly and engagements similarly terminable.

Hiring markets, at which servants and farmers meet and make engagements, are still held at many centres throughout the country; but there is a growing tendency to avoid these public fairs and have the engagements made by private inquiry or through registry offices. This is especially the case with women servants.

For harvest-work extra hands are engaged, in some parts at fairs held in towns and villages. With the self-binder fewer extra harvest hands are now required than in former times.

Average Weekly Earnings.

In his Report on the Earnings of Agricultural Labourers, published by the Board of Trade in 1905, Mr Wilson Fox gives the following table showing the average earnings per week (including the value of all allowances of all kinds) of able-bodied adults, excluding stewards, bailiffs, foremen, and casual labourers in England, Wales, Scotland, and Ireland:—

FARM-SERVANTS AND WAGES.

Average Earnings per Week.

	Ordinary Agricultural Labourers.					All Classes of Agricultural Labourers (in- cluding Ordinary Labourers and Men in Charge of Animals). 1902.
	1902.	1898.	Increase in 1902 as compared with 1898.			
			Amount.	Per cent.		
England .	s. d.	s. d.	s. d.		s. d.	
	17 5	16 9	0 8	4.0	18 3	
Wales . .	17 7	16 6	1 1	6.6	17 3	
Scotland .	19 5	18 2	1 3	6.9	19 3	
Ireland . .	10 9	10 2	0 7	5.7	11 10	

Rise in Wages since 1850.

In the Report already referred to, Mr Wilson Fox gives the following table showing the course of wages on a large

number of farms in England, Scotland, and Ireland between 1850 and 1903,—the rates are expressed in percentages, the year 1900 being taken to represent 100:—

	1850.	1860.	1870.	1880.	1890.	1900.	1903.
England and Wales	64	76	82	91	90	100	101
Scotland . .	50	60	71	85	91	100	103
Ireland . . .	56	63	71	81	90	100	101

Wages and Earnings in English Counties.

From returns made to the Board of Trade, it is learned that the average cash wages and earnings of farm-servants in different English counties varies considerably. In the southern and south-western counties the average weekly cash wages of all ordinary agricultural labourers range from 11s. 11d., with 15s. 6d. of total earnings (including the value of allowances in kind) in Dorset, to 16s. 6d. of cash wages and 18s. 10d. of total earnings in Monmouthshire, and 16s. 4d. of cash wages and 20s. of total earnings in Surrey. In the counties of Berks, Wilts, Dorset, and Gloucester, the total average weekly earnings are under 16s.; in Kent they reach 19s. 7d.; in Sussex, Hamps, Devon, and Cornwall, they run from 17s. to 17s. 9d.

In the eastern English counties the average weekly cash wages vary from

12s. 8d., with 16s. 1d. of total average earnings, to 15s. 6d., with total average earnings of 18s. 8d. in Lincolnshire. In none of the other south-eastern counties do the weekly earnings quite reach 17s.

In the midland English counties higher rates are reached. The lowest is in Oxfordshire, where average cash wages are only 12s., with total earnings of 14s. 6d. The county of Derby is highest, with average cash wages of 18s. 8d. and total earnings of 20s. 7d. Middlesex comes next, with average cash wages of 17s. 10d. and total earnings of 20s. 4d.

In England the highest rates are paid in the northern counties. Durham county stands highest, with average cash wages of 20s. and total earnings of 22s. 2d. per week. Northumberland comes next, with average cash wages of 19s. 4d. and total earnings of 21s. 7d. The lowest in the northern English counties is the North Riding of Yorkshire, with average cash

wages of 16s. 9d. and total earnings of 18s. 10d.

In arriving at the total earnings the estimated value of every allowance in kind is included, a free house being reckoned at £4 per annum.

Wages and Earnings in Wales.

Throughout Wales the cash wages and earnings are similar to those prevailing in England. The minimum is perhaps a trifle higher and the maximum somewhat lower. For married men the general run of average cash wages is from 15s. to 17s., with total earnings of from 16s. to 18s. 6d.; the highest in any county being cash wages of 20s. and total earnings of 21s. 3d. in Glamorganshire, and the lowest cash wages of 14s. and total earnings of 16s. 10d. in Radnorshire. The allowances in kind make up less of the total earnings in Wales than in England as a whole.

Wages and Earnings in Scotland.

In Scotland it is the custom to state wages for either six or twelve months. In the south-eastern Border counties the average yearly cash wages of ploughmen range from £42, with total earnings of £50, to £43, with total earnings of £53, 10s. In most cases in these counties cattlemen have very similar earnings, in some cases 20s. to 30s. less in the twelve months. The earnings of shepherds, on the other hand, are as a rule a trifle higher than those of ploughmen and cattlemen.

In the midland counties, notably in the Lothians, Stirling, Fife, and in the Glasgow districts of Lanark and Renfrew, the total average earnings of ploughmen and cattlemen mount up to from £51 to £57 per annum. In the counties of Perth, Forfar, and Aberdeen, the general average is from £50 to £52. In the counties north of the Spey the total average earnings of ploughmen and cattlemen varies from £35, 10s. in Caithness, Orkney, and Shetland, to £46 in most parts of Moray and Inverness. In these northern counties shepherds have slightly higher earnings than either ploughmen or cattlemen. In almost all parts of the country, excepting near manufacturing centres, general farm labourers earn from £4 to £6 less per annum than ploughmen.

Wages and Earnings in Ireland.

In Ireland the earnings of farm servants compare unfavourably with the figures quoted for Scotland and England, for the former in particular. In Ulster the total weekly average earnings of general farm workers (including the value of allowances in kind) range from about 10s. in county Fermanagh to 13s. in the counties of Down and Antrim; in Leinster the range is from 10s. 6d. in several counties to 12s. 9d. in county Dublin; in Munster from 9s. 6d. in county Clare to 11s. in county Waterford, and in Connaught from 8s. 9d. in county Mayo to 9s. 9d. in county Galway.

In the case of ploughmen and other male servants hired and boarded in the farmer's house the cash wages range from about £12 to £28 in Ulster, from £10 to £18 in Leinster, from £10 to £20 in Munster, and from £10 to £16 in Connaught. In estimating the total earnings of these men the sum of 5s. per week is added as representing value of their board and lodging.

Variation in Wages, Perquisites, and Work Hours.

The rates of wages, as well as the form in which payment is made, differ greatly throughout the country. The tendency in recent years is in the direction of short engagements, with weekly or monthly payments.

South-east of England.—The men are to a large extent hired on weekly engagements, but as a rule they get regular employment. Hours of work in summer and winter for horse-men on many farms are from 5.30 A.M. to 5.30 P.M., with intervals of twenty minutes or more at 11 A.M. and 3 P.M. In other cases the hours are from 5 A.M. to 6 P.M. in summer, and from 6 A.M. or 7 A.M. to 5 P.M. in winter, with intervals for meals. For cattle-men the hours are often longer; for ordinary labourers summer hours are often from 6.30 A.M. to 8.15 A.M., from 8.45 A.M. to 12 noon, and from 1 P.M. to 5.30 P.M.; in winter, 7 A.M. to 12 noon, and 1 P.M. to 5 P.M.

As to wages, horse-men usually get from 12s. to 14s. per week in cash wages, with free house and garden and certain other perquisites, in some cases straw

for pigs, food for fowls, and fuel carted ; in other cases some potatoes or potato-ground and food and beer in harvest. Cattle-men generally get similar wages and allowances to horse-men, ordinary labourers getting rather less on an average.

South-west of England.—On the whole, the arrangements as to engagements and hours of work differ but little from those in the south-eastern counties. On many farms the hours in summer are from 6 A.M. to 6 P.M., with half an hour for breakfast and an hour for dinner; and in the hay and corn harvest from 5 to 8 P.M., with intervals for breakfast, lunch, dinner, and tea. Milkers and others engaged amongst cattle usually begin the day's work at 5 or 5.30 A.M., and finish at 5 or 6 P.M. Wages and allowances are similar to those in the south-east.

Midland English Counties.—In the midland counties very general work hours in summer are from 6 A.M. till 6 P.M., with half an hour for lunch and an hour for dinner. Except in the hay and corn harvest men usually stop work on Saturdays at 4 P.M. In harvest time the hours are, as a rule, from 5.30 A.M. to 7 P.M., with intervals for breakfast, lunch, dinner, and tea. Weekly engagements are general, but most of the servants get constant employment. Wages are a trifle higher than farther south, common terms for horse-men being from 13s. to 17s. per week, with allowances valued at from £2 to £5 per annum. In many cases married men get less money and free house, with allowances of potatoes or potato-ground, fuel carted, and food in harvest.

North of England.—Over the northern counties of England farm-servants are both better paid and more comfortably housed than in the southern English counties. The men are usually hired by the year or half-year, and married men in most cases have free houses and gardens, about 17s. to 18s. per week, or less money and allowances of food or other perquisites. Unmarried men usually get about £32 to £36 per annum, with board and lodging. On many farms the terms are, for horse-men and the better class of cattle-men and general workers

about 17s. per week, with free house and garden, coal carted, about 1000 yards of potato-drill, and straw for pigs. Sons living with their fathers get 800 to 1000 yards of potato-drill in addition to their money wages.

Hours of work on farms in the north of England are, as a rule, from 6 A.M. to 6 P.M. in summer, with a short interval for breakfast and an hour and a half or longer for dinner. In harvest time longer hours are worked, and allowances of food and beer are given. In winter the work hours for horse-men are from daylight to dark, with meal hours as in summer.

Scottish Counties.—Throughout the greater part of Scotland the wages of farm-servants are substantially above the average rates in England. In regard to food the Scottish servants are also better treated, while there is greater regularity in hours of work and leisure. When daylight permits, the usual work hours in Scotland are 6 A.M. to 6 P.M., with two hours, from 11 A.M. to 1 P.M., for dinner. Extra hours are worked in harvest. Yearly or half-yearly engagements still predominate in Scotland, but weekly and monthly engagements are growing in favour.

Berwickshire.—In cases where men are paid by the "old boll," the allowances for ploughmen are, per annum: £12 to £14 in money; 60 bushels of oats; 30 bushels of barley; 1800 yards potato-ground; one cow housed and fed; free house and coal driven; butcher-meat for one month in harvest. When paid by money, the rate is: 13s. to 14s. per week, with a cow's keep, 1800 yards of potato-ground; or 16s. to 17s. per week if no cow is kept. Women at farm-work get 10s. to 11s. per week in the summer half-year, and 9s. to 10s. per week in the winter, with 15s. per week in the few weeks of the grain harvest.

Farm grieves get about £10 more. Cattle-men get about the same as ploughmen. Shepherds have similar perquisites, but instead of money most of them are allowed to keep a "pack" of their own, consisting perhaps of about 10 ewes and 3 hogs, it often being a condition that they keep a strong lad, who receives about 9s. per week. The shepherds on the Cheviot Hills will have about 50 Cheviot ewes and

hogs in their own "pack," with a cow's keep, three loads of oatmeal, and coal or "peat" driven. The general tendency now is to lessen the perquisites and increase the payment in money. It is very doubtful if this change is advantageous to the servants.

The Lothians.—In the Lothians and other central counties, farm-managers who have entire charge get from £60 to £80 a-year, a cow's keep, 1 ton dressed potatoes, and in some cases free coals and light. Working grieves get £30 to £40, a cow's keep, 1 ton of dressed potatoes, 40 to 65 stones oatmeal, $\frac{1}{2}$ quarter wheat, harvest food or £1 for same. Ploughmen, when a money wage is agreed upon, get 15s. to 17s. a-week, 16 cwt. to 1 ton of dressed potatoes, harvest food or £1 for same. When the payment is in money and meal, the ploughman gets £30 to £34, with 65 stones oatmeal, 16 cwt. to 1 ton dressed potatoes, harvest food or £1 for same. Ploughmen on the "gains" system get £24 to £28, 65 stones oatmeal, 16 cwt. to 1 ton dressed potatoes, $1\frac{1}{2}$ quarter barley, $\frac{1}{2}$ quarter beans (some get in place of barley and beans 2 quarters wheat), harvest food or £1 for same. Cattle-men of the best class get about the same wage as a ploughman, but have extra for Sunday labour, generally £1. Women get about 11s. per week, with harvest wages and food for a month, or, in place of harvest wages and food, £2. Some also get extra pay during potato-lifting.

West of Scotland.—In the west of Scotland the good old system of boarding the servants in the farmer's kitchen still survives, although it is not so general as in former times. On an Ayrshire farm, with half-yearly engagements, the rates are: ploughmen from £12 to £18 per half-year, with board and lodging; dairy-maids from £11 to £14 per half-year; general women servants, for wintering cattle, house and outdoor work, from £8 to £10; and lads from £5 to £10—all with board and lodging.

In districts near towns or mining centres wages are higher than in other parts, ploughmen getting up to 21s. or 22s. per week, with free house.

North-east.—In the districts along the east coast north of the river Tay, the terms of engagement and rates of

wages are very similar. Grieves or farm-managers get from about £45 to £60 in cash per annum, with free house and garden, oatmeal, milk, potatoes, and fuel, equal to £20 to £25 a-year. Married ploughmen get from £28 to £36 in cash, with free house and garden, with oatmeal, milk, potatoes, and fuel, equal to about £15 to £18 a-year. Unmarried ploughmen get from £25 to £34 a-year, with board and lodging, or lodging in "bothies," and certain allowances of oatmeal, milk, potatoes, and fuel.

In the counties north of the river Findhorn the rates of wages are less than farther south in Scotland by from about £4 to £8 per annum, the arrangements as to housing and food being similar.

Farm-Managers.

Men engaged for the complete or partial management of farms are known variously as Farm-managers, Stewards, Bailiffs, Grieves, and Overseers. They are paid, as has been seen, sums ranging from £40 to £100 a-year or more, according to the size and character of the farm under their care, and in addition they usually get a free house, garden, and other perquisites. In many cases the first horse-man is engaged at two or three pounds of extra wages, on the understanding that he assists the farmer in directing the work of the farm. On medium-sized farms it is quite a common practice for the griever to work the first pair of horses.

The Care of Farm-Horses.

Throughout the greater part of the southern and midland counties of England it is the usual practice to hire men specially for taking care of farm-horses when they are not at work. These men take the horses from the ploughmen when the work hours are over, and attend to them till the return of the working hours. When not fully employed in attending to the horses these men join with other workers in the ordinary farm work.

Over a large part of the north of England and throughout Scotland the prevailing custom is for the men who work the horses to attend to all their wants when they are not at work, the men asking turn about in looking after

the horses on Sundays. Scottish ploughmen greatly prefer to have the entire care of the horses that are their companions in their hours of labour.

Piece-work Employment.

The custom is growing of arranging with labourers for the execution of ordinary farm operations by "piece-work," the labourers engaging to thin or lift turnips, cut hay or grain crops, clean or raise potatoes, or such other work, at an agreed on price per acre, or by some other method. Where casual labour has to be depended upon to any considerable extent, the "piece-work" plan is found to be advantageous alike to the farmers and the men. Almost invariably the labourers earn higher wages than in the ordinary way, and it rarely happens that the cost to the farmer is greater—not infrequently it is less—while the work is usually got through with exceptional expedition.

LAW OF FARM-SERVICE.

"Arles."—It is not necessary to give earnest or "arles" to servants when hiring them, unless such be the universal custom of the district; but if such a custom does prevail, the engagement is not complete unless earnest be given. A servant who has received "arles" on engagement is not entitled to dissolve the engagement by returning the "arles."

Period of Engagement.—Farm-servants are presumed to be hired for one year when no specified period of endurance is stipulated, and when no other period is to be presumed from the circumstances of the contract or the custom of the district. If a servant be engaged for a period differing from the customary period, and particularly if the engagement is to endure for more than one year, it is desirable that the agreement be in writing and signed by both parties.

Travelling Expenses.—In ordinary circumstances the master is not bound to pay the expense incurred by the servant in going to the place where the engagement is to be fulfilled, or in returning after the termination of the engagement; but when servants are brought from a

great distance, it is usual for the employer to pay the expense of their removal to the place of service.

Board and Lodging.—A master is bound to receive his domestic servant to his or her situation, and to provide the servant with bed and board during the period of the service, unless there be an agreement to the contrary. A male domestic servant may be compelled to reside out of his master's house, the master paying expenses, but a female is entitled to the protection of her master's house. A master is not bound to provide medical attendance or medicine to a servant in sickness, even in cases where the servant is entitled to bed and board from the master. But if the master himself call in the medical man, or authorise this to be done, he will be liable for the bill, and will not be entitled to charge the servant with the amount, or retain it out of the wages.

Duties of Servants.—Servants are bound to serve their masters in everything relating to the situation for which they have engaged themselves. They must be respectful to their master and his family, and in their general conduct avoid actions scandalous or of bad example. They have no right to absent themselves without leave. They are responsible for everything committed to their charge in the routine of their duty, but not for such accidents as are not attributable to their fault. They have no right to draw nice distinctions between what comes within their duty and what does not; but they cannot be employed against their will on any duty really different from the customary duties of the service which they have undertaken, and therefore any unusual branch of service should be matter of special arrangement when the engagement is made.

Payment of Wages, &c., and Breach of Engagement.—Where the amount of wages is not fixed, the customary amount, or such amount as the Court in case of dispute shall fix as reasonable, will be payable. The servant has a right to leave his master and claim wages (and board wages if entitled to board) should his wages not be paid at the terms agreed on or implied from the engagement. The servant may also leave in the event

of any other serious breach by the master of the conditions of the employment, but should, where practicable, first endeavour to have the grievance remedied. Though a farm-servant be engaged by the year, his wages are payable half-yearly.

Death or Bankruptcy of Employer.

—When the master dies during the engagement, wages, and also board wages, if the servant be entitled to board, are due to the servant to the next term (not within the period of notice) or to the end of his engagement if that be earlier. But the servant should make reasonable exertions, if called on, to get another situation, and on the new engagement commencing, the wages in respect of the former will cease. While in receipt of wages after his master's death, the servant is bound to continue service.

The effect on the engagement of the master's bankruptcy is similar to the effect of his death. Domestic and farm servants have for long enjoyed in Scotland a preference for their wages for the current term on the death or bankruptcy of their master. In England by statute the same preference is accorded to them as to other servants.

A master may at any time turn off his servant on paying him full wages to the end of the engagement, including board wages, if the servant is entitled to board.

The marriage of a servant is not a ground for dismissal; and if a servant leaves service on marriage, the master may have a claim for any damage which he may sustain against the servant, and in the case of a female servant, against her husband.

Enlistment is not a justification of breach of his engagement by any servant, but may give rise to a claim of damages at the instance of the master. A servant unjustifiably leaving or failing to enter on the master's service may not only forfeit all claim for wages for any period for which service has been rendered; but is liable for the damages resulting from his desertion.

Dismissal.—A servant may be dismissed for immoral conduct, disobedience, or habitual neglect of duty, or for absence without leave, or other serious fault; but remonstrance is expected of a master for the less serious faults before resort is had to dismissal. Legal dismissal forfeits the

right of the servant to wages even for the period of actual service; but in some cases, where the dismissal, though justifiable, has not been for the gravest fault, and the forfeiture of wages would be disproportionate to wages earned, the Court has held that the servant is entitled to wages for the period of actual service. A servant is bound to leave, when dismissed even without sufficient or any cause, and by leaving quietly does not forfeit right to compensation for wrongful dismissal.

Notice of Leaving.—If a master wishes to part with a servant, or the servant wishes to leave his situation, at the expiry of the engagement, reasonable warning must be given, unless the local custom is to give no warning. The period of warning requisite in the case of agricultural and domestic servants, engaged for a year or for half a year, is forty days. If timeous warning be not given on either side, the engagement will be held to be renewed for one year, or such less period as may be usual in the particular occupation and locality.

Character.—A master is not bound to give a servant a character, or to state his reason for withholding it. If he knowingly give an untrue character, he will be responsible for the damages consequent on his act. But if, when asked for a character, he gives it to the best of his belief, he will not be liable to the servant in damages, although the character be unfavourable and injurious to the servant.

Sickness or Accident.—If a servant be disabled from performing his service by sickness or accident attributable to his own fault, wages will not be due for the period of disablement, but the servant may in case of accident be entitled to compensation as aftermentioned. In no case will a servant be entitled to both wages and compensation concurrently. A short temporary disablement in the course of service, not attributable to the servant's fault, will not entitle the master to retain part of the servant's wages, particularly if the illness of the servant has not necessitated the employment of a substitute. What length of disablement will entitle a master to provide a substitute, or to terminate the engagement and cease payment of wages, depends upon the circumstances of each case.

If a servant die between terms, his representatives are entitled to wages for the period during which he gave his service.

Workmen's Compensation Act, 1906.

Important new rights are conferred on agricultural servants, both male and female (as on other servants), by the Workmen's Compensation Act, 1906. That statute provides that if the servant shall sustain personal injury by accident arising out of and in the course of the employment, the employer, subject to the statutory rules, shall be liable to pay compensation. The leading statutory provisions are these: (a) If the injury does not disable the servant for a period of at least one week from earning full wages at the work at which he was employed, the employer is liable in no compensation under the Act; (b) If the injury arises from the personal negligence or wilful act of the employer, or of some other for whom he is responsible, the Act does not prevent the servant claiming damages irrespective of the Act,—but the servant cannot get both damages irrespective of the Act and compensation under the Act; (c) If the injury is attributable to the serious and wilful misconduct of the servant, no compensation is payable unless the injury results in the servant's death or serious and permanent disablement.

In case of the injury resulting in death, the scale of compensation is as follows: (a) If the servant leaves dependants wholly dependent on his earnings, a sum equal to the servant's three years' earnings immediately before the injury, or £150, whichever is the larger sum, but not more than £300; (b) If the servant leaves only persons partly dependent on his earnings, such sum, limited as already mentioned, as shall be reasonable and proportionate to the injury to such partial dependants; (c) If the servant leaves no dependants, then the expenses of medical attendance and burial not exceeding £10.

Where the injury results in the servant's total or partial incapacity for work, the compensation is a weekly payment during the incapacity, not exceeding one-half of the servant's average weekly earnings before the accident,—the payment

not exceeding £1 weekly. But a servant under 21 years of age earning less than £1 weekly may, during total incapacity, receive his full wages, not, however, exceeding 10s. weekly. In no case of partial disablement is the weekly compensation to exceed the difference between the average earning power of the servant before and after the accident. In each case where the incapacity does not last two weeks there is no compensation for the first week. In computing earnings, the computation is not to be based only on money wages, but on the amount or value of all that is truly earned.

The amount of compensation (within the limits stated) will be fixed (unless the parties agree otherwise) by the Sheriff (in England "the County Court Judge") as an arbiter in a simple way.

The servant should, before leaving the employment, and as soon as possible after the accident, give written notice of it to the employer. This may be done in an ordinary letter to the employer, stating simply the facts, including the date on which the accident happened and the cause of the injury. And a definite claim, stating the compensation demanded, should be lodged with the employer within six months of the accident, or if the accident be fatal, within six months of the death.

The amount of weekly compensation may be reviewed by the Sheriff (in England "the County Court Judge") from time to time. The employer may, after six months, redeem the compensation for a lump sum. The servant should, when required by the employer, allow himself to be examined by the employer's medical man. When parties agree as to the amount of weekly compensation, it is desirable that two copies of the agreement be written out and signed by both parties—one copy being kept by each party,—and it may be advantageous for the servant, and even for the employer, to send a copy of the agreement to the Sheriff-Clerk (in England "the Registrar of the County Court") to be registered.

Some diseases, such as anthrax, may be equivalent to an accident.

Cases of an intricate character may arise under the statute—for example, when a servant is employed by a subcontractor. When difficulty arises, un-

less the parties can make a mutually satisfactory arrangement, the prudent course is to seek legal or other expert advice with a view to a fair settlement according to the general scope of the Act—each party refraining from seeking undue advantage based on technicalities or verbal subtleties.

Employers now frequently insure against liabilities to servants, whether under the Workmen's Compensation Act, or other Act, or otherwise. With this the servant has no concern. The principal points to be noted by the employer in that case are: (a) to select an Insur-

ance Company of undoubted status; (b) to see that the premium is moderate and is regularly paid; (c) to read the form of policy proposed, including indorsed conditions, in order to be sure that it covers all risk and is free from unreasonable conditions; and (d) to keep the policy, and a copy of the employer's proposal for it, at hand, so that continuous compliance by the employer with the conditions may be assured, and particularly, that in case of accident due notice be timeously given to the Insurance Company, and the conditions otherwise observed.

SOILS.

Bearing in mind what has been already said about the origin and formation of soils (pp. 18, 19), we may at once proceed here to consider soils and subsoils in their agricultural relations.

Soil.—The *soil* proper, in the usual acceptance of the term, means the upper few inches of the mantle of unconsolidated material which covers the earth's surface. It is a complex mixture of a number of substances derived from the waste of the rocks which form the earth's crust, with the addition of some organic matter, the remains of plants and animals, and in which many interesting and important changes, due both to chemical action and to the activities of the various micro-organisms with which the soil-substance teems, are continually in progress.

Subsoil.—The *subsoil* is literally the under-soil, the bed or stratum of earth immediately underlying the cultivated soil. In residual soils, other than peat, it differs from the upper soil only in being less weathered, or less finely disintegrated; and it contains less organic matter than the surface-soil. Often, as on wet and ill-drained clays, it is densely compacted by the long-repeated travel of horses in the furrow, in conjunction with the pressure of the plough-sole, and becomes what the farmer calls "hard-pan" or "plough-pan." In gritty clay soils, in moist climates, the clay particles are apt to get washed out of the upper layer

and settle in the subsoil. This effect is, however, a very partial one, and does not explain the differentiation of soil and subsoil, which is due partly to physico-chemical causes, and partly to the action of organic matter and micro-organisms, which latter, if not altogether confined to the upper layer of the soil, are largely restricted thereto. Apart from its value as a feeding-ground for the roots and plants, great importance attaches to the character of the subsoil, more especially as to the facility with which it allows water to pass through it, as it is only where water passes that air and the roots of plants can follow.

Active Soil.—The *active soil* is not limited to the surface-soil, nor yet to the so-called subsoil, but includes the whole mass of soil in which the roots of plants are free to grow, and in which there must necessarily be, as a first condition of fertility, a constant renewal of both air and moisture. This mass of soil is what the farmer has to handle, and the total mass concerns him quite as much as the shallow surface layer; for although the actual tillage by implements may be a mere scratch (and, if a fine surface tilth is constantly maintained, it need never be more, as far more powerful and effective agencies will do the deeper tillage required, free, gratis, and for nothing, if they are only given the chance to work), yet the fertilising effects of air, heat, and

moisture, and the chemical changes which they induce, are not confined to the few inches of soil in which the plough works, but are in active operation from the surface down to the drain level, three feet or more in depth. In all this mass of soil there is not one inert particle. All are active; and incessant changes are in active progress amongst them: for in the manufacture, the waste, and the renewal of fertility, each one of them is intimately concerned.

Different Kinds of Soils.—The leading characters of all soils are derived from only two earths, *clay* and *sand*, the greater or less admixture of which stamps their peculiar character—for the properties of these earths are found to exist in calcareous and vegetable soils.

Clay Soil.—A pure *clay* soil has such distinctive external characters that it may easily be recognised. When fully wetted, it feels greasy to the foot, which slips upon it. It has an unctuous feel in the hand, by which it can be kneaded into a smooth homogeneous mass, which retains the shape given to it. It glistens in the sunshine. It retains water upon its surface, and renders water very muddy when mixed with it, and the mud is long of settling to the bottom. It feels cold to the touch, and soils everything that touches it. It cuts like soft cheese with the spade. It parts with its moisture slowly. When dry, it cracks into numerous fissures, becomes hard to the foot, and collects into lumps, very difficult to be broken. It absorbs moisture readily, and adheres to the tongue. When neither wet nor dry it is tough, and soon becomes hard with drought or soft with rain. On these accounts it is the most obdurate of all soils to manage, being, even in its best state, heavy to turn over with the plough, and difficult to pulverise with the other implements; and when wet, is in an unfit state to be wrought with any of the implements. A large number of horses is thus required to work a clay farm; and its workable state continues only for a short time, even in the best weather. But it is a powerful soil in its capability, bearing luxuriant crops, and producing them of an excellent quality. It generally occurs in deep masses, on a considerable extent of flat surface, ex-

hibiting few undulations, along the margin of a large river or its estuary, and evidently being a deposition from deep water. It is a naturally fertile soil, containing little vegetable matter, and of a yellowish-grey colour.

Sandy Soil.—A pure *sandy* soil is also easily recognised. When wet it feels firm under foot, and then admits of being turned over by the plough with a pretty entire furrow. It feels harsh and grating to the touch, and will not compress into a ball with the hand. When dry it feels soft, and is so yielding that every object of weight sinks into it, and it is very apt to be blown away with the wind. Sandy soil generally occurs in deep masses, near the termination of the estuaries of large rivers, or along the sea-shore; and in some countries in the interior of Europe, and over a large proportion of Africa, it covers immense tracts of flat land, and has evidently been brought into its place by water.

Soil of Clay and Sand.—When clay is mixed with sand, its texture as a soil is very materially altered. When such a clay is in a wet state, it still slips under the foot, and feels harsh rather than greasy. It retains water on its surface for a time. When dry it feels hard; and when betwixt the state of wet and dry, is easily reduced to a fine tilth or mould.

Loamy Soil.—Loam, in modern phraseology, consists of any kind of earth containing a *sensible admixture of decomposed vegetable matter*,—a *sensible* admixture is mentioned, as there is no soil under cultivation, whether composed chiefly of clay or of sand, but contains some decomposed vegetable matter. Unless, therefore, the decomposed vegetable matter of the soil so preponderates as to greatly modify the usual properties of the constituent earths, the soil cannot in truth be called by any other name than a clayey or sandy soil; but when it does so prevail, a *clay loam* or a *sandy loam* is formed—a distinction well known to the farmer. Hence it is possible for husbandry to convert any earthy soil into a loam, as is clearly exemplified in the soil in the vicinity of large towns.

Clayey Loams.—A *clay loam* constitutes a useful and valuable soil. It

yields the largest proportion of the finest wheat raised in this country, occupying a larger surface of the country than the carse clay. It forms a lump by the squeeze of the hand, but soon crumbles down again. It is easily wetted on the surface with rain, and then feels soft and greasy; but the water is absorbed, and the surface soon becomes dry. It is easily wrought, and may be so any time after a day or two of dry weather. It becomes finely pulverised; is generally of some depth, forming an excellent soil for wheat, beans, swedes, and red clover; and is of a deep brown colour, often approaching to red.

Gravelly Soil.—Sandy soils are divided into two varieties, which do not vary in kind but only in degree. Sand is a powder, consisting of small round particles of siliceous matter; but when these are of the size of a hazel-nut and larger—that is, gravel—they acquire the distinctive name of a *gravelly soil*, which, when mixed with a sensible proportion of vegetable matter, becomes gravelly loam. Gravelly deposits sometimes occupy a large extent of surface, and are of considerable depth. Such a soil never becomes wet, absorbing the rain as fast as it falls, and after rain feels somewhat firm under the foot. It can be easily wrought in any state of weather, and is not unpleasant to work, although the small stones with which it abounds render ploughing rather unsteady. This soil is admirably adapted to plants with bulbs and tubers; and no kind of soil affords so dry and comfortable a lair to sheep on turnips in winter, and on this account it is distinguished as "*turnip soil*."

Sandy Loams.—*Sandy and gravelly loams*, if not the most valuable, are the most useful of all soils. They become neither too wet nor too dry in ordinary seasons, and are capable of growing every species of crop, in every variety of season, to considerable perfection. On this account they are esteemed "*kindly soils*." They never occur in deep masses, nor do they extend over large tracts of land, being chiefly confined to the margins of small rivers, forming haughs or holms, through which these rivers direct their course from amongst the mountains towards the larger rivers, or even to the sea.

Chalky Soils.—Besides these, there are soils which have for their basis another kind of earth—*lime*, of which the *chalky* soils of the south of England are examples. These differ in agricultural character according to the particular formation in which the chalk is situated. If the chalky soil is derived from flinty chalk, then its character is similar to that of a sandy soil; but if from the hard chalk formation, its character corresponds more nearly to that of clay.

Peaty Soils.—These are the neglected soil-assets of the nation; and a pretty large asset too, seeing that there are some 6,000,000 acres of bog land in the United Kingdom. Many of the peat mosses, notably Cleat-moss, and others, have been reclaimed, and are now growing good crops of all kinds; but the great value of peat lands lies in their industrial as well as in their agricultural possibilities.

Peat has been formed chiefly by the growth of the bog-moss, *Sphagnum*, in moist places. A section in a peat-bog, from the top downwards, shows (1) a layer of living moss, &c., chiefly the matted thread-like stems of the *Sphagnum*, which continues to grow upwards while dying below; (2) a layer of dead moss fibres, whose structure is clearly recognisable; and (3) a layer of fully formed peat, a dense, brownish-black mass, in which the vegetable structure is often indistinct.

All peat-bogs, except in the fens, are, till drained, from 7 to 15 feet, according to the thickness of the peat they contain, above the water-level of the country. On proper drains being dug, it will alter the surface of the bog from its natural shape to that of a convex one, and the middle or highest ground will be wettest, which is contrary to every other soil whatever.

Peat is in the nature of a sponge; for when dry it will absorb double its weight of water; and its retention is such that it will discharge none of the water without pressure. Its capillarity, or attraction for water, is as great as its retention, and if a column of dry peat is left in contact with water at its base, the water will ascend and make the top of the column damp in a short time.

Position of Soil and Subsoil.—As we have already seen, the subsoil may consist of the same earthy substance as the soil itself, or it may be of quite an opposite character, or it may consist of hard rock. An endeavour is made to illustrate the varieties by a figure of soils and subsoils. Let *a*, fig. 279, be the surface of the ground, the earthy mould derived from the growth and decay of natural plants; *b*, a dotted line, the depth of the plough-furrow. Now, the plough-sole may either just pass through the mould, *a*, when the mould will be the soil, and the earth below it, *b*, the subsoil; or it may not pass entirely through it, as at *c*, when the soil and subsoil will be both of mould; or it may pass through the earth below the mould, as at *d*, when the soil and subsoil will again be similar, while neither will be

mould, but earth; or it may move along the surface of *e*, when the soil will be of one kind of earth, not entirely of mould, and the subsoil of another — of sand, gravel, or clay; or it may penetrate to *f*, when the soil will be of earth, a mixture of clay, sand, and mould, and the subsoil of hard rock. These different cases of soils and subsoils, each forming a distinct sectional division, may so occur in nature, though probably not all in the same locality.

Influence of Subsoil.—The subsoil undoubtedly produces a sensible effect on the condition of the soil above it. If the soil is clay, it is impervious to water, and if the subsoil is clay also, it also is impervious to water. The immediate effect of this juxtaposition of retentiveness is to render both soil and subsoil continually wet, until

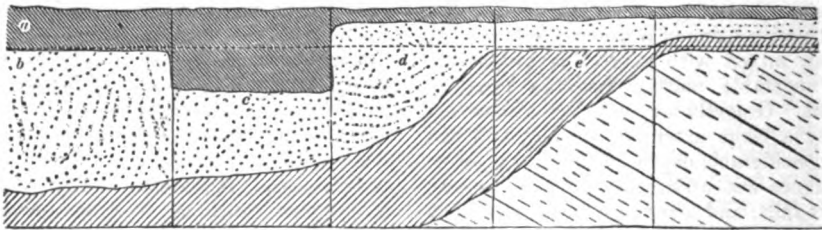


Fig. 279.—Sections of soils and subsoils.

evaporation dries first the soil and then the subsoil. A retentive subsoil, in like manner, renders even a porous soil above it wet. On the other hand, a gravelly subsoil, which is always porous, greatly assists to keep a retentive clay soil dry. When a porous soil rests upon a porous subsoil, scarcely any degree of humidity can injure either. Rock may be either a retentive or a porous subsoil, according to its structure — a massive structure keeping the soil above it always wet; while a stratified one, with the stratification dipping downwards from the soil (as at *f*, fig. 279), will preserve even a retentive soil above it in a comparatively dry state.

Depth of Soil.—Beyond a certain narrow limit, depth does not add to the fertility of a soil, nor to its actual value for cultivation and cropping. Some soils, alluvial deposits, &c., are 10, 20, 30, or even 60 ft. in depth, and of good quality

from top to bottom; yet they are no more fertile than if the deposits were only 3 or 4 ft. in depth. Other soils, on rocky outcrops, and on the chalk formation, have only a few inches of cultivable soil, yet their fertility never diminishes, under rational cultivation; although, no doubt, a greater depth in these cases would admit of deeper tillage, and afford a wider feeding-ground for the roots of plants. But in any soil, no matter how great its depth, even when highly fertile from top to bottom, *the top spit*, of 9 inches, or even less, is the real feeding-ground of the plants. Even if there is unlimited depth, the second spit will not be drawn upon to half the extent of the first, nor the third spit to half the extent of the second; and in the absence of a second or third spit in depth, we have seen the upper spit produce as abundantly almost as if there had been no limit to the depth.

CLASSIFICATION OF SOILS.

The classification of soils should be made as simple as possible. Soils being made up chiefly of sand, clay, lime, and organic matter, these four constituents may be taken as types of all the infinite variety of soils. Those containing 75 per cent and upwards of silica should be classed as siliceous or *sandy soils*; those containing 66 per cent and upwards of silicate of alumina, as argillaceous or *clay soils*; those containing 50 per cent and upwards of carbonate of lime, as calcareous or *lime soils*; and those containing 33 per cent and upwards of organic matter, as *vegetable soils*. From these four we may deduce every other variety of soil, in respect of the predominant or leading ingredients. Thus, for example¹ :—

Sand + clay = a loam.
 Clay + lime = a marl.
 Sand₂ + clay = a sandy loam.
 Clay₂ + sand = a clay loam.
 Clay₂ + lime = a clay marl.
 Lime₂ + clay = a calcareous marl.
 Sand + vegetable matter = a light vegetable soil.
 Clay + vegetable matter = a heavy vegetable soil.
 Lime + vegetable matter = a calcareous vegetable soil.

Dawson, in this respect, proposes the following classification :—

Pure Clay : from this no sand can be extracted by washing.

Strong Clay : a brick clay, containing less than 20 per cent of sand.

Clay Loam : has from 20 to 40 per cent of sand.

Loam : has from 40 to 60 per cent of sand.

Sandy Loam : has from 60 to 80 per cent of sand.

Sand : has less than 20 per cent of clay.

Soils are also classed according to their mode of origin, as *residual* and *transported*.

Residual soils "are formed by rock weathering, and found resting on the parent rock from whose decay they have originated; they consequently, in most instances, show a gradual transition from the surface-soil to the parent rock be-

neath. With this class there is sometimes grouped the humus or peaty soils, formed by the accumulation of vegetable matter in bogs or swamps." ²

Transported soils are the materials which *in situ* would have formed residual soils, but have been carried off to a distance by moving water, ice, wind, or other agencies, and deposited in a more or less mixed state. Thus soils transported by water include (1) *alluvial soils*, deposited by water on the low land bordering rivers or on their deltas, and these are one of the most important soil types, the fertile soils of the Nile Valley and the Mississippi bottoms being of this class; and akin to these are (2) *Lacustrine and Estuarine clays*, deposited in lakes and estuaries; (3) *Marine clays*, deposited where rivers empty into the open sea.

The second class of transported soils form the *Glacial Drift Soils or Till*, sometimes called boulder-clay. *Till*, from its origin, must consist not only of true clay, but mostly of more or less undecomposed rock-material partly reduced by grinding action to a fine powder or rock-flour, and partly in fragments varying in size from mere pebbles to large boulders. The approximate percentages, according to E. G. Loughlin,³ are :—

Gravel, 25 per cent.

Sand, 20 per cent.

Rock-flour, 40 to 45 per cent.

True clay, less than 12 per cent.

The third class of transported soils are *Eolian Clays*, &c., which have been deposited by wind. Of this class are the *loess* soils of Central China and other regions.

There is another mode of soil classification which will interest British farmers, because it is a method of expressing the relative value of different soils for rental purposes. In India, where the Government represents the landlord, the Bombay Revenue Survey base their classification chiefly on the depth, but also on the colour and texture, of the soils, which they divide into 9 classes and 3 orders, as follows :—

¹ *The Farm Valuer*, by John Scott.

² *Ries's Economic Geology*.

³ *Industrial Clays*.

Class.	Anna Valuation.	Order I.	Order II.	Order III.
		Uniform fine texture, black to dark brown in colour.	Uniform coarse texture, lighter in colour, usually red.	Gravelly, or loose friable texture, colour light brown to grey.
		Cubits.	Cubits.	Cubits.
1	16	1 $\frac{3}{4}$	...	...
2	14	1 $\frac{1}{2}$	1 $\frac{3}{4}$	...
3	12	1 $\frac{1}{4}$	1 $\frac{1}{2}$	...
4	10	1	1 $\frac{1}{4}$	...
5	8	$\frac{3}{4}$	1	...
6	6	$\frac{1}{2}$	$\frac{3}{4}$	1
7	4 $\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{4}$
8	3	...	$\frac{1}{4}$	$\frac{1}{2}$
9	2	...	...	$\frac{1}{4}$

The depth of the soil determines the class. The colour and adhesiveness determine the order. A greater depth than 1 $\frac{3}{4}$ cubit does not affect, to an appreciable degree, the fertility of the land. Soils of the third order are never found more than 1 cubit deep.

The following conventional signs for faults are used for the Bombay Revenue Survey Soil Classes to indicate the nature of deficiencies in soils classified according to the above table:—

°° denotes a mixture containing nodules of limestone.

V denotes an inordinate mixture of sand.

/ denotes a sloping surface.

X denotes absence of cohesion amongst the soil particles.

Λ denotes more or less imperviousness to water.

— denotes liability to be swept away by running water.

□ denotes excess of surface water from springs, &c.

These comprise all the important faults of the soils hitherto met with by the classers, who are instructed to reduce the class of a soil by one for each such fault.

SOIL CONSTITUENTS.

Soil, to be useful to the agriculturist, must contain at least 11 different chemical substances—viz, silica, alumina, oxide of iron, lime, magnesia, potash, soda, phosphoric acid, sulphuric acid, chlorine, and organic matter. In addition to these, titanium, iodine, and fluorine occasionally occur in soils; as,

indeed, do some of the still rarer elements, or rather their compounds, but they do not appear to be either necessary or beneficial. "*Titanium*, though a very constant ingredient of soils in the form of titanic dioxide, is not known as performing any important function in soils, and is not, so far as known at present, ever taken up by plants. *Iodine* is normally present in all sea-weeds, and occurs in traces in some land plants. *Fluorine* is a normal ingredient of animal bones, and its presence in plant ashes is often easily shown."¹

Organic Matter in Soils.—The organic matter of the soil, which consists of the remains of plants and animals, is usually found in the upper layers. It is of great value, in constantly yielding, by its decay, carbonic acid and nitrates to nourish the organic part of the plant; in setting free, little by little, the earthy matter of its own ashes; in, also by its decay, inducing chemical changes, which tend to set free other matters held in combination in particles of the soil; in rendering clay soils more friable, and sandy soils more retentive of volatile substances and of substances in solution; and in giving a darker colour to the soil, and making it more receptive of solar heat.

There are, however, "some alluvial soils nearly destitute of organic matter, yet of almost inexhaustible fertility; and there are some peaty soils very rich in organic matter, and yet very barren."²

¹ Hilgard's *Soils*.

² Dawson's *Principles of Agriculture*.

In ordinary soils less than 5 per cent of organic matter is not desirable.

Humification.—What proportion of the amount of organic matter present in a soil ultimately becomes converted into *humus*, or vegetable mould, depends upon a great variety of circumstances. The main controlling conditions in humification are: the amount of water or moisture present; the access of air (oxygen); a proper temperature; and the presence of the several organisms which take part in the process of soil formation.

"In the presence of only a moderate amount of moisture, under the influence of a more or less rapid circulation of air, and in the presence of earthy carbonates (especially that of lime), to prevent the formation of acids, or to neutralise them as formed, *the normal process of humification occurs*, mainly under the influence of fungous instead of bacterial growth, and always accompanied by the evolution of carbonic acid gas.

"Natural humification takes place only under the influence of moderate temperature. When the temperature is too low, bacterial or fungous growth is repressed or arrested; when too high, the fungous vegetation assumes a different phase, the result of which is the almost total oxidation of the organic matter, sometimes so accelerated as to imitate rapid combustion ('fire-fanging' of dung), leaving in any case but a trifling organic residue of very high contents.

"In the absence of a sufficient degree of moisture to co-operate with the other agencies of humification, the final result in the soil is practically the same as in the 'fire-fanging' of dung. The organic matter is almost wholly destroyed by direct oxidation, with or without the aid of minute organisms, leaving essentially only the ash behind to be reincorporated with the soil. This accounts for soils in arid regions being so poor in humus-substances, they having to derive it almost entirely from the decay of roots only."¹

Excessive aeration by cultivation and fallowing result in serious losses of humus.

Chemical Changes in the Soil.—

"The elements of which the soil is composed are always shifting and changing. The compounds, which are merely combinations of several elements, are constantly dissolving partnership, and the elements join themselves together in new bonds, according to affinity.

"The nitrogen released from a nitrate by the nitrogen-wasting germ may be instantly seized by some near-by hydrogen to make ammonia. The ammonia may then be attacked by the nitrogen-saving germs and made into nitrous acid, which, in turn, may soon become a nitrate; or it may escape into the air and be lost to the soil, until brought down by the rain.

"The phosphoric acid that the farmer applies in superphosphate or bone-meal is at once seized by hungry elements, and enters into several partnerships. Some of it is readily soluble in water, and might leach away were there not some lime or sodium handy to catch it. That part of it which is not used by plants the first year or two may get locked up so strongly in partnerships with other elements that it becomes valueless to plants.

"When a potash fertiliser, as wood ashes, is applied to the soil, the plant food it contains would mostly dissolve in the soil water and wash away were it not that it unites with some of the 'bases' of the soil and becomes 'fixed.' In fact, the plant food in most fertilisers applied to soils would be quickly leached or washed away, if these chemical changes did not occur and hold it until the roots of plants can use it.

"Plants feed, not upon the materials that we apply to the soil, but upon the chemical compounds formed in the soil by them.

"These and other chemical changes that all fertilisers pass through before they are absorbed by the roots of plants, illustrate what takes place with each and every constituent of the soil, whether it is essential to the growth of the plant or not."²

Inorganic Constituents of Soils.—All the inorganic constituents needful to

¹ Hilgard's *Soils*.

² S. W. Fletcher's *Soils: and How to Handle Them*.

the development of plants must be present in the soil or plants cannot grow upon it. But the requirements of different crops differ always in quantity and sometimes in kind. And "the percentage of any of these constituents need only be small, because a small percentage of the composition of an acre of soil, one foot deep, weighing 2000 tons (4,480,000 lb.), represents a large absolute amount, one one-hundredth of one per cent (or 0.001 per cent) being 400 lb.; but each ingredient must be present.

"Hence the mass of the soil is to be regarded, not as in itself food for plants, but only as holding and containing this food, and giving support and protection to the plant and its roots.

Available Inorganic Matter.—"Inorganic matter enters the plant only through the tender tissues of the rootlets in a state of solution. Unless, then, these matters are in such a state as to be soluble in soil water (that is, in water which holds in solution carbonic acid or alkalies, or other substances derived from the soil, or the air, or the roots of growing plants), their presence in the soluble state is of no immediate value to the plant. It is true that they need not be very soluble. Phosphoric acid in solution in soil water does not in any case exceed 1 part in 50,000; but as the formation of every pound of dry vegetable matter is attended by the evaporation of at least 250 lb. of water, this very small proportion of phosphoric acid in solution would account for 5 per cent of this substance in the vegetable structure. It is true also that the whole amount needed is not necessarily available at once. If, while a crop is growing, the chemical changes which are incessant in a soil progressively render soluble the needed nutriment as it is required, the crop will flourish; even if at no given moment of the season the soil holds ready all the nutriment required."¹

Silica in Soils.—"Silica is the pure matter of sand, and also constitutes on an average about 69 per cent of the various clays, so that in soil it generally amounts to from 75 to 95 per cent.

In its uncombined state it has no direct influence upon plants, beyond its mechanical action, in supporting the roots, &c.; but as it possesses the properties of an acid, it unites with various alkaline matters in the soil, and produces compounds which are required in greater or less quantity by every plant. The chief of these are the *silicates of potash and soda*, by which expression is meant the compounds of silica, or, more properly, silicic acid with the alkalies potash and soda.

Alumina in Soils.—"Alumina exists pure in soil. It is the characteristic ingredient of clay, although it exists in that compound to the extent of only 30 or 40 per cent. It exerts no direct chemical influence on vegetation, and is scarcely ever found in the ashes of plants. Its chief value in soil, therefore, is owing to its effects in rendering soil more retentive of moisture. Its amount varies from $\frac{1}{2}$ per cent to 13 per cent.

Oxides of Iron in Soils.—"There are two *oxides of iron* found in soils—namely, the protoxide and peroxide. The protoxide is frequently very injurious to vegetation—so much so, that $\frac{1}{2}$ per cent of a soluble salt of this oxide is sufficient to render soil almost barren. The peroxide, however, is often found in small quantities in the ashes of plants. The two oxides together constitute from $\frac{1}{2}$ to 10 per cent of soil. The blue, yellow, red, and brown colours of soil are more or less dependent upon the presence of iron.

Oxide of Manganese in Soils.—"The *oxide of manganese* exists in nearly all soils, and is occasionally found in plants. It does not, however, appear to exert any important influence, either mechanically or chemically. Its amount varies from a mere trace to about $1\frac{1}{2}$ per cent. It assists in giving the black colour to soil.

"These four substances constitute by far the greatest bulk of every soil, except the chalky and peaty varieties, but, nevertheless, *chemically speaking*, are of trifling importance to plants; whereas the remaining eight are so absolutely essential that no soil can be cultivated with any success unless provided with them, either naturally or artificially.

¹ Dawson's *Principles of Agriculture*.

And yet, when it is considered that scarcely any of them constitute 1 per cent of the soil, their value will no doubt excite surprise. The sole cause of their utility lies in the fact that they constitute the

Ashes of the Plants ;

and as no plant can, by possibility, thrive without its inorganic constituents (*its ashes*), hence no soil can be fertile which does not contain the ingredients of which these are made up. The very small percentage of these ingredients in any soil necessitates a minute analysis of every soil before it can be ascertained whether or not it contains any, or what proportion, of these ingredients. But the reason for such minuteness in analysis becomes obvious when we consider the immense weights which have to be dealt with

in practical agriculture ; for example, every imperial acre of soil, considered as only 8 inches deep, will weigh 1884 tons, so that 0.002 per cent—that is, only a two-thousandth per cent—the amount of *sulphuric acid* in a barren soil amounts to 80.64 lb. in the imperial acre !

Potash and Soda in Soils.—“*Potash and soda* exist in variable quantities in many of the more abundant minerals, and hence it follows that their proportion in soil will vary according to the mineral which produced it. For the sake of reference, I have subjoined the following table, which shows the amount per cent of alkalies in some of these minerals, and likewise a rough calculation of the whole amount per imperial acre, *on the supposition of a soil composed solely of these rocks, and of a depth of 10 inches* ; and the amount is abundant beyond conjecture:—

Name of Mineral.	Amount per cent of Alkali.	Name of Alkali.	Amount per Imperial Acre in a soil 10 inches deep.	
			Tons cwt. qr. lb.	Tons cwt. qr. lb.
Felspar . . .	17.75	Potash . . .	422 18 2 8	
Clinkstone . .	3.31 to 6.62	Potash and soda	71 17 2 0	to 143 15 0 0
Clay-slate . .	2.75 " 3.31	Potash . . .	35 18 3 0	" 71 17 2 0
Basalt . . .	5.75 " 10.	Potash and soda	17 0 0 7	" 25 7 3 7

“One acquainted with chemistry will naturally ask the question, How is it that these alkalies have not been long ago washed away by the rain, since they are both so very soluble in water ? The reason of their not having been dissolved is the following—and it may in justice be taken as an example of those wise provisions of nature whereby what is useful is never wasted, and yet is at all times ready to be abundantly supplied. These alkalies exist in combination with the various other ingredients of the rock in which they occur, and in this way have such a powerful attraction for these ingredients, that they are capable of completely resisting the solvent action of water as long as the integrity of the mass is retained. When, however, it is reduced to a perfectly impalpable powder, this attraction is diminished to a considerable extent, and then the alkali is much more easily dissolved. Now this is the case in soil, and consequently,

while the stony portions of soil contain a vast supply of these valuable ingredients in a condition in which water can do them no injury, the impalpable powder is supplied with them in a soluble state, and hence in a condition available to the wants of vegetation.

“In the rocks which we have mentioned, the alkalies are always associated with clay, and it is to this substance that they have the greatest attraction ; it follows, therefore, that the more clay a soil contains, the more alkalies will it have, but at the same time it will yield them less easily to water, and through its medium to plants.”¹

Analysis of Soil.—It may be useful to give the following *minute analysis* by Dr Anderson of a good arable light sandy loam, well fitted for the growth of turnips in Dumbartonshire.

¹ Dr Henry Madden.

<i>Soluble in water.</i>	Organic matter	5.53
	Peroxide of iron	0.37
	Lime	0.36
	Magnesia	0.49
	Potash	1.25
	Chloride of sodium	2.91
	Phosphoric acid	0.72
	Sulphuric acid	4.43
	Silicic acid	8.02

24.08

Peroxide of iron	427.02
Alumina	260.15
Lime	33.77
Magnesia	27.71
Potash	221.05
Soda	3.48
Chloride of sodium	20.66
Phosphoric acid	37.77
Sulphuric acid	5.94
Silicic acid	52.68
Organic matter	576.61
Insoluble silicate	7,988.62
Moisture	323.46

10,000.00

the other elements must exist in combination with it, as oxides.

H. S. Washington has tabulated, as follows, the results of a very large number of analyses by himself and others; alongside of which is placed a revised estimate by F. W. Clarke; both being given in terms of oxides of the several elements:—

		Washing- ton.	F. W. Clarke.
Silica	SiO ₂	57.78	59.89
Alumina	Al ₂ O ₃	15.67	15.45
Peroxide of iron	Fe ₂ O ₃	3.31	2.64
Protoxide of iron	FeO	3.84	3.53
Magnesia	MgO	3.81	4.37
Lime	CaO	5.18	4.91
Soda	Na ₂ O	3.88	3.56
Potash	K ₂ O	3.13	2.81
Water, basic	H ₂ O +	1.42	1.52
Water, acid	H ₂ O -	0.36	0.40
Ferric sulphide	FeS ₂	1.03	0.60
Phosphoric acid	P ₂ O ₅	0.37	0.22
Manganese protoxide MnO		0.22	0.10

From a chemical point of view, this arable soil, analysed previous to liming and manuring, was a good one, and contained a suitable proportion of all the necessary elements of plants, and was particularly rich in potash.

Average Composition of the Earth's Crust.—Hilgard gives the average quantitative composition of the earth's crust, as determined by F. W. Clarke, as follows:—

	Solid crust 93 per cent.
Oxygen	47.29
Silicon	27.21
Aluminium	7.81
Iron	5.46
Calcium	3.77
Magnesium	2.68
Sodium	2.36
Potassium	2.40
Hydrogen	0.21
Titanium	0.33
Carbon	0.22
Chlorine	0.01
Phosphorus	0.10
Manganese	0.08
Sulphur	0.03
Barium	0.03
Nitrogen	—
Fluorin	0.02
Chromium	0.01

All of these are not met with in all soils, nor perhaps in any one soil; but all of them have been met with in different soils. The vast preponderance of oxygen in the above list suggests that most of

Here the salient point is the great predominance of the oxide of silicon—silica, silicic acid, quartz, &c.—over all other substances. While quartz occurs alone in enormous masses, probably the greater proportion is found in combination with other oxides, notably those of aluminium, calcium, iron, manganese, and the alkali metals potassium and sodium. Chlorine and fluorine, however, do not occur in oxides.

What Plants withdraw from the Soil.—“On comparing the constituents of such a soil as the above with the mineral ingredients obtained by incineration from the ashes of plants, it is found that plants withdraw from the soil chiefly its alkaline, mineral acid, and earthy ingredients; and if all these were not essential to the very existence of the plants, they would not, of course, be taken up by them; and as the plants constituting our cultivated crops withdraw those ingredients in a varied amount, it follows that, unless the soils we cultivate contain them in ample amount and variety, it will be impossible for the plants placed upon them to arrive at a perfect state of development of all their parts; for, chemically speaking, and rationally speaking too, soils cannot be expected to produce crops abundantly unless they contain a sufficient supply of every ingredient

which all the crops we wish to raise require from them."¹

As examples of the quantities of mineral ingredients taken from the soil under culture by some of the cultivated plants, the following amounts of percentage are given:—

By grain crops—

100 lb. of	Grain.	Husk.	Straw.
Wheat . . .	1.2 to 2.0	—	3.5 to 18.5
Barley . . .	2.3 to 3.8	—	5.2 to 8.5
Oats . . .	2.6 to 3.9	5 to 8	4.1 to 9.2
Rye . . .	1.0 to 2.4	5 to 8	2.4 to 5.6
Rice . . .	0.9 to 0.7	14 to 25	—
Indian corn . . .	1.3	—	2.3 to 6.5
Buckwheat . . .	2.13	—	—
Field-beans . . .	2.1 to 4.0?	—	3.1 to 7.0
Field-pease . . .	2.5 to 3.0	Pod 7.1	4.3 to 6.2
Vetches . . .	2.4	—	—
Linseed . . .	3.8 to 4.63	—	—
Flax-seed . . .	4.5	—	1.28
Hemp-seed . . .	5.6	—	1.78
Mustard-seed . . .	4.2 to 4.3	—	—

By root and leaf crops—

100 lb. of	Root or tuber.		Leaves.	
	Undried.	Dried.	Undried.	Dried.
Potato . . .	0.8 to 1.1	3.2 to 4.6	1.8 to 2.5	18 to 25
Turnip . . .	0.6 to 0.8	6.0 to 8.0	1.5 to 2.9	14 to 20
Beet . . .	—	6.3	—	—
Carrot . . .	0.7	5.1	—	16.42
Parsnip . . .	0.8	4.3	—	15.76
Mangel-wurzel . . .	1.1	7.0	0.53	7.55
Cabbage . . .	—	—	—	18 to 26

By grasses—

100 lb. of	Green.	Dry.
Lucerne . . .	2.6	9.5
Red clover . . .	1.6	7.5
White clover . . .	1.7	9.1
Rye-grass . . .	1.7	6.0
Knot-grass . . .	—	2.3
Holcus lanatus . . .	—	5.6 to 6.8
Poa pratensis . . .	—	6.2
Scirpus . . .	—	2.3

By trees—

100 lb. of	Wood.	Seed.	Leaves, dried.
Larch . . .	0.33	5.0	6.0
Scotch fir . . .	0.14 to 0.19	4.98	2.0 to 3.0
Pitch pine . . .	0.25	4.47	3.15
Beech . . .	0.14 to 0.60	—	4.2 to 6.7
Willow . . .	0.45	—	8.2
Birch . . .	0.34	—	5.0
Elm . . .	1.88	—	11.8
Ash . . .	0.4 to 0.6	—	—
Oak . . .	0.21	—	4.5
Poplar . . .	1.97	—	9.2
Common furze . . .	0.82	flower.	3.1
Hop . . .	5.0	10.90	16.3

Inorganic Matter in Plants.—The discovery of the constant existence of inorganic matter in plants, which could have been discovered by chemistry alone, has a very important influence in regulating the practice of cultivating our plants. "It establishes a clear relation between the kind and quality of the crop, and the nature and chemical com-

position of the soil in which it grows; it demonstrates what soils ought to contain, and therefore how they are to be improved; it explains the effect of some manures in permanently fertilising and of some crops in permanently impoverishing the soil; it illustrates the action of mineral substances upon the plant, and shows how it may be, and really is, in a certain measure, fed by the dead earth: over nearly all the operations of agriculture, indeed, it throws a new and unexpected light."²

Chemical Analysis of Soils Essential.—On viewing, then, the chemical composition of soils of known natural fertility, a standard will be afforded us by which we may, perhaps, be enabled to render other soils equally fertile by artificial means; but chemical analysis alone, as a soil-determinant, is not a safe guide. A knowledge of the chemical composition of the soil has not been found to be the key to the solution of the problem. It has, indeed, never been decided just what the chemical composition should be to produce the best results, for the simple reason that it is not known exactly what the requirements of the plant are. Nor does a chemical analysis of the plant itself answer the question. There are certain elements which are no doubt necessary for proper growth, but the analysis of the content of the plant, and of the soil, does not give a very complete notion of the proper conditions under which certain substances should exist when in the soil. Soil analysis will always be of importance; but it is of less practical value than the physical and bacteriological conditions of the soil. "Chemical analysis of soils fails to answer the question how much of the nutrient material in the soil is available, or will readily become available, for the wants of a crop. It can accurately state the amount of each ash ingredient present in the soil. It can demonstrate the absolute barrenness of a soil by proving that it is destitute of some essential ingredient of the ashes of plants. It can show what amount of each ash ingredient can be leached out of the soil by water. But plants can undoubtedly take from a soil more than pure water

¹ Johnston's *Lec. Agric. Chem.*, 2d ed., 528.

² *Ibid.*, 307.

will dissolve from it (just how much chemistry cannot say); and chemistry cannot tell the farmer what additional amount will be set free during the growth of the crop by the chemical changes resulting from the development of roots in the soil, from the operation of bacterial life, from the influence of heat, moisture, and frost, and from the combined interactions of the many substances contained in the soil, or supplied to it in manures."¹

PHYSICAL PROPERTIES OF SOILS.

The physical properties of a soil are fully comprehended in its relations to air, moisture, and heat. There is not a quality or condition of soil which is not dependent on one or all of these, and which is not directly influenced by them, especially by the two first, which are largely under the farmer's control. A soil may be very rich in all the elements of plant food, but if the physical conditions of normal vegetation are absent, the rich soil-contents must remain dormant. We are slow to understand that air and moisture are the two most important substances in the soil; and that the conservation of these ever-present substances, and the bringing of them to the roots of the plants, is the chief problem of agriculture. Some soils are naturally in this favourable condition; by far the majority are not; and it is by studying the physical properties of good soils that we learn how to maintain them in that condition, and also how to improve those that need improvement.

Structure of Soils.—Structure of soil, as distinguished from texture, relates to its molecular composition, or the kinds of materials, and the proportion of each kind, which make up the mass. The farmer will more readily grasp the true agricultural meaning of soil structure if he realises that

Clay is a lamellar structure;
Sand is a granular structure;
Peat is a fibrous structure.

Hitherto he has been taught to regard a clay soil as made up of particles like a

sandy soil, only with the particles of clay in a much finer state of division. And, so far, that is true; but it is the smallest part of the truth. You may crush a particle of sand to powder and it will become 50, or more, smaller grains, and the powdered sand will still be a coarse substance compared with the finer particles of clay, of which it is estimated there are from 10,000 to 25,000 in an inch. Nor is this wonderful when we consider that gold leaf can be beaten out into leaves which are only $\frac{1}{300,000}$ of an inch in thickness, or that diatomaceous earth has been found to contain as many as 187,000,000 separate diatomic individuals in an inch. With sufficient pressure bearing on a bed of sand, the result, in time, is sandstone, with its granular structure still complete; but no amount of pressure or time would ever make a bed of clay take on the granular structure; it would merely cause the clayey particles to flatten out in thinner laminae to form shale or slate. The structural analogy is a practical one from an agricultural point of view. Pour water on an ordinary slate, and then lay another slate on top of it; it will require considerable force to pull them apart, and it is found that the attraction of water between and around the plates has imparted an adhesiveness which they did not possess when dry. It is the same with the particles of a clay soil in a wet state. The mechanically included water acts as a lubricant, and allows the plates to slide over one another but still holds them by attraction. These facts go some way to explain the peculiar relations of clay soils to water, and why their tillage is so much more difficult than the tillage of soils in which clay is not the predominating material.

Texture of Soils.—The texture of a soil refers to the fineness or coarseness of its grains. It has for long been assumed that there is a certain limit beyond which divisibility is impossible, and these ultimate particles were called atoms. It is now found, however, that even the so-called atoms consist of numerous smaller "ions" in a state of rapid vibration. These atoms, again, are assumed to be joined together by chemico-physical affinity to form molecules, which are the smallest particles of any sub-

¹ Dawson's *Principles of Agriculture*.

stance which can exist in an uncombined state.

Fineness of grain is important in soils, though it is not yet fully understood. It affects the retentive power of the soil for moisture and gases. Clay soils hold much water, and hence are wet and cold ; whereas sandy soils, on account of the coarseness of their particles, have large pores, hold little water, and warm up easily. Loamy soils stand in an intermediate position.

The essential difference, from a physical point of view, between a clay, silt, sand, and gravel, lies in the difference in size of the particles. The limits and terms adopted by the Division of Soils U.S. Department of Agriculture are as follows:—

Over 2 millimetres	= gravel.
2 to 1 mm.	= fine gravel.
1 to .5 mm.	= coarse sand.
.5 to .25 mm.	= medium sand.
.1 to .05 mm.	= very fine sand.
.05 to .01 mm.	= silt.
.01 to .005 mm.	= fine silt.
.005 to .0001 mm.	= clay.

Density (sp. gr.) and Volume Weight of Soils.—The density, or specific gravity, of a soil is its relative weight dry to an equal bulk of water. This depends upon its molecular structure, and upon the character of the individual molecules, the latter varying in weights in different elements and compounds. Thus the presence of a large amount of quartz will raise the specific gravity of a clay. The specific gravity of clays varies from about 1.70 to 2.30; of sand from 2.55 to 2.75; while that of peat ranges from about 0.50 to 0.90.

The volume weight of a soil is its absolute weight. The farmer, however, in speaking of soils, often uses the term heavy in a sense that does not refer to weight but to tenacity, as when he means that a soil is tenacious or heavy to work. Sand, the lightest to work, is, absolutely, the heaviest of soils.

Percolation of Water through Soils.—The filtrating power of the soil, or the rapidity with which water percolates to the drain level; depends on the size of the soil particles. Gasparin tested the rate of flow of water through wet soils of different kinds, and found that a layer of water 20 inches thick passed through

a layer of soil 12 inches thick, and saturated with water, in the times stated below:—

	Hours.
Coarse sand, somewhat calcareous . . .	1.54
Do., after removal of the lime 1.20	
Fine quartz sand	1.57
Sand from Hartz Forest	6.25
Limestone soil (with 11 percent humus) 7.94	
Sand, ground extremely fine	33.33
Refractory clay from a field	168.00
Tile-makers' clay	252.00

With a given rainfall, the amount of percolation water passing through a soil depends not only on the physical conditions of the soil, but on its moisture contents when rain begins to fall, on the time in which the rain falls, and on the amount of evaporation.

Evaporation from Soils.—The evaporating power of a soil, apart from the fineness of its particles, depends on temperature, on the dryness or humidity of the atmosphere, and on wind velocity. The percentage of rainfall evaporated at the surface of the ground is about 40 per cent for the whole year in the open field. Evaporation is greater from land under grass or crop than from bare soil. And, as Warrington has pointed out, "soils of various characters evaporate equal amounts while saturated, but exhibit great differences as drying proceeds."

Capillary Power of Soils.—The movement of film water in the soil is usually spoken of as capillary action—otherwise, the passage of moisture from the saturated water-level below to the dry surface-soil, in apparent violation of the laws of gravity. The tables given us on this subject are to the effect that when an inch tube is plunged into a vessel of water, the height of the water column in the tube above the general level is054 inch ; for a $\frac{1}{10}$ -inch bore545 inch ; for a $\frac{1}{100}$ -inch bore5.456 inches ; for a $\frac{1}{1000}$ -inch bore54.56 inches. While the actual surface pull of the smallest tube is much less than that of the largest, it is through a vastly greater distance, and by the multiplication of a number of such minute tubes in a given space that the greater lifting is brought about.

The soil itself, consisting of minute particles, admits of capillary action ; for the pores, although not straight, extend

in irregular lines and permit the surface tension that is evident in fine tubes. The soil, on account of its porosity, is in this way able to lift water through considerable distances, simply through the greater pull or surface attraction of a solid for the liquid than the liquid has for its own particles.

It is a great mistake to suppose that because a soil is under-drained there can be no capillary action. The drains can only carry off the free or hydrostatic water: the film water, which is the water of capillarity, remains, and cannot be drawn off by the drains below, though it can be, and is constantly being, lost by evaporation from the surface. But as fast as evaporation uses up the film water in the surface-soil, it is replenished from below by capillary action, in proportion to the minuteness of the pores of the soil. It is far more difficult to imagine continual evaporation from the surface of a dry soil without capillary action, than it is to imagine capillary action in a drained soil.

Colour of Soils.—Colour in soils is a physical property due to chemical composition. Thus, amongst clays in their natural state we find—

Colour of Clay.	Cause of Colour.
Grey to blue and black	Ferrous iron, or organic matter.
Yellow, brown, reddish	Ferric oxide in hydrated form.
White	Absence of iron and organic matter.
White effervescence	Salts soluble in water.

These are the principal colours found amongst soils.

The *colour of subsoils* is less uniform than that of soils, owing, no doubt, to their exclusion from atmospheric and tillage influences. Some subsoils are very particoloured, and the more so, and the brighter the colours they sport—such as light blue, green, bright red, bright yellow, and white,—the more injurious are they to the soils resting upon them. Dull red and chestnut brown subsoils are good; but the nearer they approach to hazel brown the better. Dull browns, reds, and yellowish greys are permanent colours, and are little altered by cultivation; but blues, greens, bright reds, and yellows become darker and duller by exposure to the air, and admixture with manures and the surface-soil.

The colours of soils have a considerable influence in regulating the quantities of heat they absorb from the sun's rays. The darker - coloured, such as black, brown, and dark reds, absorb more heat than greys and yellows.

Colour has also an influence in *retaining heat* acquired by soils from the sun, dark-coloured radiating their heat more quickly in the absence of the sun's rays than light-coloured; and colour, together with dryness, has a greater influence in warming the soil than that of the various materials composing it. Thus sand will cool more slowly than clay, and clay than a soil containing much humus.

Temperature of Soils.—The temperature of a soil depends on its colour, its texture, its aspect or exposure to the sun's rays, its degree of moistness, its drained or undrained state, and the amount of evaporation from its surface by radiation and by cold winds.

It is a fact well known to farmers that the soil becomes much more heated when exposed to the rays of the sun in a perpendicular than in a sloping direction. "When the sun is at an elevation of 60° above the horizon, as is more or less the case towards noon in the middle of summer, the sun's rays fall on the slopes of mountains, which are raised to an inclination of 30° to the horizon, at a right angle; but even in the latter months of summer the sun's rays frequently fall on them at a right angle, in cases where the slopes are yet sharper." Where the exposure and aspect of the soil are most favourably situated for absorbing the sun's rays, the light coloured will derive more benefit than the dark in a less favourable position.

If we compare the earths in their power of retaining heat with their other physical properties, we shall find it to be nearly in proportion to their specific gravities. We may therefore conclude from this, with a tolerable degree of probability, as to the greater or less power of retaining heat.

The influence of a damp or dry state of soils on their acquisition of *warmth* is also considerable. Experiments in draining bogs have shown that, when water is given a free passage through a cold soil by thorough drainage, its tem-

perature at the depth of seven inches may be raised as much as 19° Fahrenheit above that of the adjoining undrained soil.

Absorbing Power of Soils.—Excepting siliceous sand, all kinds of soil have the property of *absorbing moisture* from the atmosphere; and the absorption is greatest in clay soils, especially when they contain humus. Humus shows the greatest power of absorption. The absorption by all soils is greatest at first, and they absorb less the more gradually they become saturated with moisture, and attain that point in a few days. If exposed to the sunlight, a portion of the absorbed moisture becomes again vaporised, and this is again absorbed during the night. These daily periodic changes in respect to moisture must have a beneficial effect on vegetation.

SOIL BACTERIA.

We have seen that the soil is not the inert mass it was long believed to be, but has numerous activities within itself that exert a most potent influence on fertility. Some of these activities are physical, some are chemical, and others (certainly not of less importance) are due to germ life. In one gram—that is, in about 15 grains—of fertile soil, Adametz found 38,000 bacteria at the surface, and 460,000 at 10 inches deep; in a loam soil at the surface 500,000, at 10 inches 464,000, in each gram of earth. Of moulds and yeasts there were only 40 to 50 in the same. Most of the soil bacteria are beneficial; some are injurious.

The different species of bacteria are not yet fully classified and described; but the confusion of species does not much interest the farmer, who is at present more concerned in the results of the action of micro-organisms than with the problem of their specific characters.

Nitrifying Bacteria.—An interesting phase of soil life is the process called *Nitrification*. Most farm crops get their nitrogen, which they need in considerable quantities, solely from the soil. This nitrogen enters into their structure, and is returned to the soil when the plants decay, but not in the same form.

It enters the plant as a salt of nitrogen—a nitrate, and it returns to the soil in combination with many other substances, and is called by the chemist “organic nitrogen.” The important point about this is, that plants cannot use organic nitrogen. It must first be separated from its partners in the compounds, and then changed into a nitrate before the roots of plants can absorb it. The work of transforming valueless organic matter into valuable nitrates, which are plant food, is performed by putrefactive and by nitrifying germs.

Although the end-products—the nitrates—alone appear in the soil, the conversion of organic nitrogen into nitric takes place in three stages. First, the organic nitrogen is converted into ammoniacal nitrogen by the putrefactive bacteria; secondly, the ammoniacal nitrogen is oxidised and converted into nitrite by the nitrous bacteria; and, lastly, the nitrite is still further oxidised and converted into nitrate by the nitric bacteria.

The nitrous and nitric bacteria have quite separate functions, each being incapable of doing the work of the other. Together they are called the nitrifying bacteria. They are found in all fertile soil in inconceivable numbers, busily engaged in making nitrates out of organic matter, such as plant remains and farm-yard manure, provided the conditions are right. One essential condition is, that they have plenty of suitable food. One food is phosphoric acid, which is also one of the most important foods of ordinary farm crops. If a soil has very little phosphoric acid in it, the transformation of humus into plant-food is apt to take place very slowly. The principal food of the germs, however, is humus itself. As these bacteria are aerobic, a plentiful supply of oxygen is essential; this condition is attained if the soil be well drained and ploughed, and hence well aerated.

“Given these conditions—and they at the same time are those most necessary for the growth of crops—the germs gradually change the insoluble nitrogenous organic matter into soluble nitrates, and it is for the farmer to see that these conditions are attained.

“In order to do this, however, the

soil must contain a sufficient, but not excessive, quantity of some 'base,' as lime, to combine with the nitrous and nitric acids as fast as they are formed, and so prevent the soil becoming at all acid. If the soil is at all acid or sour, the germs cannot thrive and perform their work.

Denitrifying Bacteria.—"There are also at work in some soils bacteria that accomplish a result exactly opposite to that of the nitrifying germs. The process is spoken of as 'denitrification,' and the germs may be called nitrogen-wasting-germs. They feed upon the nitrates, either previously formed or artificially added, and set free the nitrogen as gas, which then escapes into the air, and so is lost to the soil and crop."¹

Fortunately, the amount of denitrification which takes place in the hands of a good agriculturist is small and unimportant, for the conditions at which he aims—viz., those which favour nitrifying bacteria—simultaneously render denitrifying bacteria inactive.

Only when quantities of nitrate are used on water-logged, and therefore non-aerated, land, or when they are used with excessive amounts of fresh unrotted dung—both of which are very bad practice—are denitrifying bacteria likely to be active and cause loss of nitrogen.

The action of useful bacteria in the soil, particularly in connection with leguminous crops, is dealt with fully in the section on "The Fertility of Soil" (pp. 324, 325), and therefore need not be considered here.

DISCRIMINATING SOILS BY THE PLANTS THEY PRODUCE.

There is another method by which the physical characters of soils and subsoils, such as have been explained, may be discriminated—namely, by the *plants which grow upon them*. This test, however, cannot be relied on so confidently as the chemical composition, or the external characters given above, for distinguishing soils.

Notwithstanding the difficulties attending the discrimination of soils by plants,

it is an undoubted fact that plants do affect certain soils, as also certain conditions of the same soil. Such plants are limited in number, and may therefore be easily remembered. Only such as have come under our own observation need be enumerated—separating those which grow upon the soil, in a state of nature, from those which make their appearance after the land is in cultivation.

Weeds.—Every plant—other than that which it is intended to grow—found among cultivated corn, green crops, and sown grasses, is a *weed*.

On good *clay* soils, in a state of nature, in the low country, these herbaceous plants will be found—

<i>Spiraea ulmaria</i> . . .	Queen of the meadow.
<i>Angelica sylvestris</i> . . .	Wild angelica.
<i>Ranunculus lingua</i> . . .	Great spearwort.
<i>Rumex acetosa</i> . . .	Common sorrel.

After such soils are in cultivation, these *weeds* appear, which have been sown either with corn, grass seeds, or carried by the wind, or amongst the dung—

<i>Rumex obtusifolius</i> . . .	Common broad-leaved dock.
<i>Senecio vulgaris</i> . . .	Groundsel.
<i>Lapsana communis</i> . . .	Nipple-wort.
<i>Agrostemma githago</i> . . .	Corn-cockle or popple.
<i>Matricaria chamomilla</i> . . .	Wild chamomile.
<i>Sonchus oleraceus</i> . . .	Common sow-thistle.

Thin clays, in their natural state in the low country, yield the following plants—

<i>Ranunculus acris</i> . . .	Bitter crowfoot, erect buttercup.
<i>Aira cespitosa</i> . . .	Tufted hair-grass.
<i>Equisetum arvense</i> . . .	Corn horse-tail.
<i>Stachys palustris</i> . . .	Marsh woundwort.

Thin clays become clay loams under cultivation, and then yield these *weeds*—

<i>Tussilago farfara</i> . . .	Common colt's-foot.
<i>Sinapis arvensis</i> . . .	Wild mustard, charlock.
<i>Polygonum aviculare</i> . . .	Knot-grass.

On deep strong clayey loam, on a porous subsoil, in a state of nature, in the low country, these plants are found—

<i>Silene infanta</i> . . .	Bladder campion.
<i>Linaria vulgaris</i> . . .	Toad-flax.
<i>Scabiosa arvensis</i> . . .	Field scabious.
<i>Centaurea scabiosa</i> . . .	Great knapweed.
<i>Polygonum amphibium</i> . . .	Redshank.
<i>Dactylis glomerata</i> . . .	Cock's-foot grass.

On thin strong clayey loam, on a porous subsoil, in a state of nature, in the low country, these plants are found—

<i>Ononis arvensis</i> . . .	Common rest-barrow.
<i>Trifolium arvense</i> . . .	Hare's-foot clover.
— <i>procumbens</i> . . .	Hop clover.

¹ S. W. Fletcher's *Soils and How to Handle Them*.

After cultivation, both deep and thin clay loams, on a porous subsoil, in the low country, yield these *weeds*—

<i>Anagallis arvensis</i> . . .	Scarlet pimpernel.
<i>Veronica hederifolia</i> . . .	Ivy-leaved speedwell.
<i>Sinapis nigra</i> . . .	Black mustard.
<i>Vicia hirsuta</i> . . .	Hairy tare or fetter.

Plants peculiar to *sandy* soils, in a state of nature, in the low country are—

<i>Lotus corniculatus</i> . . .	Bird's-foot trefoil.
<i>Campanula rotundifolia</i> . . .	Common bluebell.
<i>Euphrasia officinalis</i> . . .	Eyebright.
<i>Anthoxanthum odoratum</i> . . .	Sweet-scented vernal grass.

After cultivation these *weeds* appear—

<i>Spergula arvensis</i> . . .	Common spurry.
<i>Lamium purpureum</i> . . .	Purple dead-nettle.
<i>Fumaria officinalis</i> . . .	Common fumitory.
<i>Capella bursa-pastoris</i> . . .	Shepherd's-purse.
<i>Soleranthus annuus</i> . . .	Common knawel.
<i>Gnaphalium germanicum</i> . . .	Common cudweed.
<i>Triticum repens</i> . . .	Common couch-grass.

Upon *sandy loam* on clay subsoil, in a state of nature, in the low country, are these plants—

<i>Juncus effusus</i> . . .	Common or soft rush.
<i>Achillea ptarmica</i> . . .	Sneezewort.
<i>Potentilla anserina</i> . . .	Goose-tongue or silver-weed.
<i>Artemisia vulgaris</i> . . .	Mugwort.

After cultivation, these *weeds* appear—

<i>Raphanus raphanistrum</i> . . .	Wild radish or "runch."
<i>Rumex acetosella</i> . . .	Sheep's sorrel.
<i>Chrysanthemum segetum</i> . . .	Corn marigold.
<i>Juncus bufonius</i> . . .	Toad-rush.

Sandy loam, upon a porous subsoil, in a state of nature, in the low country, yield these plants—

<i>Cytisus scoparius</i> . . .	Common broom.
<i>Centaurea nigra</i> . . .	Black knapweed.
<i>Galium verum</i> . . .	Yellow bed-straw.
<i>Senecio jacobææ</i> . . .	Common ragweed.

When cultivated, the soil yields these *weeds*—

<i>Mentha arvensis</i> . . .	Common corn-mint.
<i>Centaurea cyanus</i> . . .	Corn blue-bottle.
<i>Sherardia arvensis</i> . . .	Field madder.
<i>Lithospermum arvense</i> . . .	Corn gromwell.
<i>Alchemilla arvensis</i> . . .	Parsley-piert or field lady's-mantle.
<i>Avena elatior</i> . . .	Tall oat-grass.
<i>Cnicus arvensis</i> . . .	Corn-thistle.

Alluvial deposits, in a state of nature, in the low country, yield a vegetation indicative of wet clay soil and subsoil—

<i>Arundo phragmites</i> . . .	Common reed.
<i>Juncus conglomeratus</i> . . .	Round-headed rush.
<i>Agrostis alba</i> . . .	Flour grass.
<i>Glyceria aquatica</i> . . .	Reed meadow-grass.
— <i>fluitans</i> . . .	Floating meadow-grass

These plants disappear on cultivation, except the common reed, which keeps possession of the soil for an indefinite time amidst the best cultivation. Where such soil is indifferently cultivated, the corn-thistle, *Cnicus arvensis*, is a very troublesome *weed*.

Besides these soils, there are others in the low country which cannot be rendered arable, but form the sites of numerous plants, which find their way into the adjoining arable soils. From the sea-beach, gravel-pits, and sandy downs, plants stray by the assistance of the wind upon any kind of arable soil in their respective neighbourhoods.

On *gravel*, as found in the *débris* of mountains, occasioned by the disintegration of indurated rocks, the vegetation is different from that of the beaches, and is the same as the alpine plants of the district. In gravel in the low country these plants are found—

<i>Polygonum aviculare</i> . . .	Knot-grass.
<i>Rumex acetosella</i> . . .	Sheep's sorrel.
<i>Agrostis vulgaris</i> . . .	Common bent-grass.
<i>Aira caryophyllæa</i> . . .	Silver hair-grass.
<i>Festuca duriuscula</i> . . .	Hard fescue-grass.
<i>Arenaria serpyllifolia</i> . . .	Thyme-leaved sandwort.
<i>Hieracium nurorum</i> . . .	Wall hawkweed.
<i>Papaver dubium</i> . . .	Long smooth-headed poppy.
— <i>Rhæas</i> . . .	Common scarlet poppy.
<i>Polygonum convolvulus</i> . . .	Climbing buckwheat.
<i>Chenopodium urticum</i> . . .	Upright goose-foot.
<i>Lolium perenne</i> . . .	Perennial rye-grass.
<i>Bromus mollis</i> . . .	Soft brome-grass.

Gravel on the sides of rivers producing these plants indicates a wet subsoil—

<i>Juncus bufonius</i> . . .	Toad-rush.
— <i>articulatus</i> . . .	Jointed rush.
<i>Littorella lacustris</i> . . .	Plantain shore-weed.

Drifting sands, links, or dunes have this peculiar vegetation—

<i>Elymus arenarius</i> . . .	Sea lyme-grass.
<i>Triticum junceum</i> . . .	Sand wheat-grass.
<i>Festuca duriuscula</i> . . .	Hard fescue-grass.
<i>Carex arenaria</i> . . .	Sand carex.
<i>Galium verum</i> . . .	Yellow bed-straw.

The vegetation of *moory* ground only a little elevated varies according to the wetness or dryness of the subsoil. Wet moors are characterised by these plants—

<i>Salix repens</i> . . .	Dwarf silky willow.
<i>Pinguicula vulgaris</i> . . .	Butterwort.
<i>Carex pitulifera</i> . . .	Round-fruited carex.
<i>Juncus squarrosus</i> . . .	Moss-rush.
<i>Parnassia palustris</i> . . .	Grass of Parnassus.

On dry moors, containing a proportion of peat-earth, and resting on a porous subsoil, these plants are found—

<i>Gentia anglica</i> . . .	Needle green-weed.
<i>Nardus stricta</i> . . .	Mat-grass.
<i>Viola lutea</i> . . .	Yellow mountain-violet.
<i>Potentilla tormentilla</i> . . .	Common tormentil.
<i>Gnaphalium dioicum</i> . . .	Mountain cudweed.

Marshes in the interior of the country produce these plants—

<i>Lychnis flos-cuculi</i> . . .	Ragged robin.
<i>Menyanthes trifoliata</i> . . .	Fringed buckbean.
<i>Callitha palustris</i> . . .	Marsh marigold.
<i>Veronica beccabunga</i> . . .	Brooklime.
<i>Comarum palustre</i> . . .	Marsh cinquefoil.
<i>Galium uliginosum</i> . . .	Marsh bed-straw.

After marshy ground has been cultivated, these *weeds* retain a strong hold—

<i>Tussilago farfara</i> . . .	Common colt's-foot.
<i>Petasites vulgaris</i> . . .	Common butter-bur.
<i>Galium aparine</i> . . .	Goose-grass or cleavers.

On *peat* or *moss* the vegetation differs as it is wet or dry. On dry spots these plants are found—

<i>Erica tetralix</i> . . .	Cross-leaved heath.
<i>Calluna vulgaris</i> . . .	Common ling.
<i>Agrostis canina</i> . . .	Dog bent-grass.

In wet hollows in peat these plants establish themselves—

<i>Eriophorum polystachion</i> . . .	Cotton-grass or sedge.
<i>Vaccinium oxycoccus</i> . . .	Cranberry.

Cultivated peat is infested with these *weeds*—

<i>Bromus mollis</i> . . .	Soft brome-grass.
<i>Myosotis arvensis</i> . . .	Field scorpion-grass.
<i>Avena fatua</i> . . .	Wild oats.
<i>Galium aparine</i> . . .	Goose-grass.

On *mountain pastures* plants are numerous. At moderate heights these prevail—

<i>Calluna vulgaris</i> . . .	Common ling.
<i>Dryas octopetala</i> . . .	Mountain avens.
<i>Salix reticulata</i> . . .	Reticulated willow.
<i>Gnaphalium alpinum</i> . . .	Mountain cudweed.
<i>Rubus chamaemorus</i> . . .	Cloud-berry.
<i>Arbutus uva-ursi</i> . . .	Common bear-berry. ¹

In very elevated mountain pastures these plants are found on peaty soil—

<i>Calluna vulgaris</i> . . .	Common ling.
<i>Empetrum nigrum</i> . . .	Crowberry.
<i>Erica tetralix</i> . . .	Cross-leaved heath.
<i>Lycopodium clavatum</i>) . . .	Club-moss.
<i>alpinum</i> }	
<i>Juncus squarrosus</i> . . .	Moss-rush.
<i>Equisetum palustre</i> . . .	Paddock-pipe.
<i>Scirpus cespitosus</i> . . .	Deer-hair.
<i>Narthecium ossifragum</i> . . .	Bog asphodel.
<i>Melica cerulea</i>) . . .	{ Fly-bent, rot-grass, or
<i>Sesleria caerulea</i> }	{ blue moor-grass.
<i>Nardus stricta</i> . . .	Wire-bent or mat-grass.

In wet mossy places these thrive—

<i>Juncus effusus</i> . . .	Soft rush.
<i>Holcus lanatus</i> . . .	Yorkshire fog.
<i>Carex cespitosa</i> . . .	Risp.
<i>Juncus articulatus</i> . . .	Jointed rush.
<i>Carex panicea</i> . . .	Pry.
<i>Scabiosa succisa</i> . . .	Devil's-bit scabious.
<i>Hypnum palustre</i> . . .	Marsh-fog. ²

Professor Macgillivray truly remarked that "no soil that we have examined has been found to produce plants peculiar to itself, excepting *sand* and *peat*; and these two soils, so different from each other in their mechanical and chemical nature, also form a striking contrast in respect to the plants growing upon them, each being characterised by a vegetation differing in aspect and qualities from each other, and scarcely agreeing in any one circumstance." The existence of *peat* is invariably indicated by *Calluna vulgaris*, common ling,—*Erica cinerea*, fine-leaved heath,—and *Erica tetralix*, cross-leaved heath; and loose sand is as invariably covered with *Psamma arenaria*, sand-reed, most frequently accompanied by *Triticum junceum*, sand wheat-grass, and *Galium verum*, yellow bed-straw. Too much, however, must not be made of this, for Scots Pine may be found growing on dry sand and in wet peat, while *Vaccinium uliginosum* and other peat plants are also found on the cold dry soils of polar regions. This may seem puzzling when the great dissimilarity in physical condition is considered. As a matter of fact, however, the cold soil, the wet peaty soil, and the sandy soil agree in being dry soils as far as the plants are concerned. Water, even if present, cannot pass in at the roots of the plant unless the soil has a certain temperature; where humus acids are plentiful, absorption of water is prevented. These soils, then, are physiologically dry soils, while the sandy soil may be physically a dry soil.

In as far, then, as the arable soils are concerned, the information imparted by their *weeds* possesses greater interest to the farmer than their natural vegetation; and they give a truer account of the state of the soils at the time than of their nature, although this even is not overlooked. For example, *clayey*

¹ Trans. High. Agric. Soc., vii. 123.

² Ibid., vii. 281.

soils are indicated by the existence of the grasses, and of these the genera of *Poa*, *Agrostis*, and *Festuca* prevail.

Gravelly soils are indicated by *Aira caryophyllæa*, silvery hair-grass; *Aira præcox*, early hair-grass; and *Rumex acetosella*, sheep's sorrel. When intermixed with a little clay, the grasses also appear.

Good vegetable soil is indicated by *Trifolia*, *Vicia*, and *Lathyrus pratensis*. *Thymus serpyllum*, wild thyme, indicates a thin vegetable mould; and ragweed, *Senecio jacobæa*, one of depth. Where ragweed prevails, sheep are absent, as they fondly eat down its young leaves.

Purge-flax, *Linum catharticum*; autumn hawkbit, *Leontodon autumnalis*; and mouse-eared hawk-weed, *Hieracium pilosella*, indicate a dry soil,—the *Galium verum*, yellow bed-straw, one very dry.

Yellow iris, *Iris pseud-acorus*; the jointed rush, *Juncus articulatus*; lady's smock or cuckoo-flower, *Cardamine pratensis*; and ragged robin, *Lychnis flos-ruculi*; the purple dead-nettle, *Lamium purpureum*; and smooth naked horse-tail, *Equisetum limosum*, assure us of a supply of moisture below.

The broom, *Cytisus scoparius*, indicates a pernicious, and the whin, furze, or gorse, *Ulex europæus*, a favourable subsoil.

The common nettle, *Urtica dioica*; common dock, *Rumex obtusifolius*; mugwort, *Artemisia vulgaris*; annual poa, *Poa annua*; smooth-stalked poa, *Poa pratensis*; and common tansy, *Tanacetum vulgare*, grow near the dwellings of man; while white clover, *Trifolium repens*; red clover, *Trifolium pratense*; hoary plantain, *Plantago media*; ribwort or ribgrass, *Plantago lanceolata*; purple meadow-vetch, *Vicia cracca*; and common daisy, *Bellis perennis*, are found in the pasture around his house.

Common chickweed, *Stellaria media*; and common fumitory, *Fumaria officinalis*, indicate a rich condition of soil.

The great ox-eye, *Chrysanthemum leucanthemum*, points out a soil in a state of poverty; and its poverty from want of manure is indicated by the parsley-piert, *Alchemilla arvensis*.

Wild mustard or charlock, *Sinapis arvensis*, tells of manure having been derived from towns.

The common corn-thistle, *Cnicus arvensis*, is a tell-tale that the land is not well farmed.

Wherever there is the least admixture of peat, the *Erica* or *Calluna* and spotted-bearded orchis, *Orchis maculata*, are sure to be there.

General View of the Relation of Plants to Soils.—Taking a more extended view of the indications of the condition of soils by plants, the observations of Dr Singer are graphic: "*Green mountains*, like those of Cheviot and Ettrick Forest, abounding in grass without heath, indicate a strong soil, which is rendered productive, though frequently steep and elevated, by a retentive subsoil. This quality, and the frequent mists and showers that visit rather elevated sheep-walks, render them productive in strong grasses (*Agrostis*). . . . *Dark mountains*, clothed with a mixture of heath and grass, indicate a drier soil on a less retentive bottom. Such are many of the Highland mountains, and such also are some of those which appear occasionally among the green mountains of the southern pastoral district, in which the light soil is incumbent commonly on gravel or porous rock. On these dark-coloured mountains, a green and grassy part often appears where there is no heath, and the subsoil is retentive; and if the upper edge of such a spot appears well defined, this is occasioned by the regular approach of a stratum of clay or other substance impervious to water towards the surface, and the green hue disappears below, when the subsoil again becomes open. . . . On any of the mountains, whether dark or green, when the fern or bracken, *Pteris aquilina*, appears in quantities, it indicates a deep soil and a dry subsoil."

A stunted growth of heath indicates a part having been bared by the paring-spade; and when vegetation becomes of a brown colour in summer, the subjacent rock is only a little way under the surface.

Viewing the connection of plants to the soil on the great scale, one cannot but be forcibly impressed with the conviction that "the grand principle of

¹ *Trans. High. Agric. Soc.*, vii. 264.

vegetation is simple in its design ; but view it in detail, and its complication astonishes and bewilders." And yet, as Professor Macgillivray justly observed, "it is the same sun that calls forth, and, thus elicited, gives vigour to the vegetation, the same earth that supports it, the same moisture that swells its vessels, the same air that furnishes the medium in which it lives ; but amid all these systems of general, how multiple the variations of particular constituent causes, and how infinitely diversified the results !"

WATER AS A FACTOR IN ENVIRONMENT.

Apart from and along with the chemical and physical properties of soils in their influence on plants, there are other factors of environment—*e.g.*, water, temperature, light, exposure to wind, animals, &c. Of all of these, none is more important than water. Limiting our view to land plants, and taking water as a prime factor, we have three sets of plant societies—the Xerophytes, the Hygrophytes, the Tropophytes.

Xerophytes are plants whose water-supply or content is in danger either from factors which prevent absorption by the root, or by factors which cause over-evaporation, or by a combination of these. Absorption at the root is reduced when the actual water in the soil is scarce in amount, or when the soil is too cold—and a water-logged soil is a cold soil, and may really be a physiologically dry soil as far as the plant is concerned—or when there is too great an abundance of soluble salts in the soil, or when the soil is too rich in humus acids. Over-evaporation—*i.e.*, the outgo of water greater than the intake—is occasioned by too dry an atmosphere with drying winds or too high a temperature.

Habitats for Xerophytic plants are deserts, rocks, sea-shores, peat-bogs, high-exposed mountains. Such plants solve their problem by increasing their intake or lessening their outgo of water, adapting themselves to their environment as regards water in different ways—*e.g.*, increasing their root system, protecting their stomata by the leaves rolling up as with fescue grasses on exposed hillsides and bent grasses by the seaside, by rolling

their leaves backwards to cover the stomata as in heaths, by becoming hairy so that wind cannot dry them up, by reducing their evaporating surfaces and becoming spiny as in whin, by storing water in fleshy swollen parts, by growing together in tufts so that the wind cannot get free play at them.

Hygrophytes, on the other hand, are plants which are in no danger from lack of water. While damp tropical forests are the real home of Hygrophytes, we find such plants in our country by the sides of streams or in close sheltered woods. The risk that a Hygrophyte runs is the stagnation of the transpiration current ; this, amongst other things, would mean a lessening of food material passing in at the roots. We meet in such plants adaptations which tend either to reduce absorption at the roots or to increase evaporation at the leaves.

Tropophytes are plants which during one part of the year are in danger from physiological drought—*i.e.*, are Xerophytes—while during the other part of the year they are Hygrophytes. This is the characteristic vegetation of a country such as ours, where a cold season alternates with a warm one.

In our country winter for such plants is the physiologically dry season. The soil being too cold for absorption, evaporation of water by above-ground parts must be prevented or limited, hence trees shed their leaves, have their stems covered with bark, and the tender leaves of their buds with bud-scales ; while herbaceous plants may sacrifice all their above-ground parts, and persist by some storing underground, and, therefore, protected parts—*e.g.*, rhizome, corm, tuber, bulb. On the other hand, such trees and herbaceous plants, in summer no longer in danger of drought, clothe themselves with leaves.

Evergreen plants have special ways of protecting themselves against physiological drought.

Distribution of Plants, or Zones of Vegetation.

The earth has been mapped out into zones of vegetation, each zone being characterised by societies of plants with similar adaptations to their environment

of water, heat, light. Willis,¹ following Drude,² enumerates the six zones:—

1. Northern Glacial Zone—viz., the Arctic region south to the tree limit. The growing period is represented by about 3 months. Characteristic of this zone are mosses, lichens, and perennial herbs and shrubs that are xerophytic.

2. The Northern Zone of cold winters, from the northerly limit of trees to the south of France and Greece in Europe, to about 50° N. in Asia, most of Canada, the New England States, and as far south as Utah in the Western States. Vegetation lasts from 3 to 7 months with the summer not too hot and dry. Characteristic are forests of deciduous broad-leaved trees and of conifers. The undergrowth in these forests, in addition to some shrubs and grass, shows many spring flowers, while later in the year, when the trees are in full leaf and their crowns tend to shade the soil, saprophytes like *Monotropa* and the bird's-nest orchid appear. In other places the lower trees occur—hawthorn, hazel, willow. Another formation is the heaths and heathers and gorse. This, too, is the zone of Gramineæ, and of such Natural Orders as Compositæ, Campanulaceæ, Labiata, Scrophulariaceæ, Umbelliferæ, Onagraceæ, Leguminosæ, Geraniaceæ, Crucifera, Caryophyllaceæ, Ranunculaceæ, Polygonaceæ, Liliaceæ, Juncaceæ.

3. The Northern Zone of hot summers—viz., the Mediterranean basin; Asia south of Zone 2 (except India, Indo-China, the Malay Archipelago, and the S.E. coast of Arabia); North Africa, including the Sahara; the rest of the United States and Mexico. The summer temperature is very high, with the nights often cold. There is practically no winter. Characteristically the vegetation is xerophytic. Conifers are found, trees and shrubs that are chiefly evergreens, although there are also deciduous species which have their leaves in wet seasons and shed them in dry. Copse formations are found, and extensive steppes and prairies dried up in the summer. In the Sahara and the drier parts of Mexico the plants are extreme xerophytes.

4. Tropical Zone—the land between the Tropics. There is no cold to interrupt growth, but in most of the continental parts there is a dry season of 3 months, interrupting vegetation and occasioning xerophytic characters. In west Equatorial Africa, the south of India, south Ceylon, the Malay Archipelago, the Amazon valley, and the extreme north of Australia, there is rain all the year round, with a typical tropical vegetation. The trees here are evergreens, mostly with straight trunks—palms, bananas, bamboos. Very characteristic in the forests are climbing plants and epiphytes. Parasitic plants are also common; and here, too, are found the myrmecophilous plants, the plants which live in partnership with ants. In the part of this region where there is a dry period the vegetation is xerophytic, cacti and spurge appearing in large numbers. Savannahs, covered with grasses, sedges, and other plants, are also found.

5. Southern Temperate Zone with hot summers. This zone includes all south of the last zone except the regions to be named in the 6th zone. Cold interrupts the vegetative period more or less. In Victoria, Tasmania, and part of New Zealand, where there is rain all the year round, forests of evergreen and deciduous trees are found, and also many conifers. Paraguay and Eastern Australia have forests with few conifers. Chili, S.E. Cape Colony, and parts of Australia are characterised by a scrub of evergreen plants and stunted trees usually xerophytic in character. Then the Pampas, the desert of Kalahari, and a great part of Australia, have grasses and other low herbs exposed to drought in the dry season, and therefore Xerophytic in habit.

6. Southern Cold Zone. This region embraces South Patagonia, a belt in the Tasmanian mountains, and New Zealand and the Antarctic region. Its vegetation corresponds with that of the Northern Glacial Zone.

THE FERTILITY OF SOIL.

From an agricultural point of view, all else relating to the soil is wrapt up in the question of its fertility. The fer-

¹ J. C. Willis's *Flowering-Plants and Ferns*, i. 196.

² Drude's *Handbuch der Pflanzengeographie*.

tility of the soil, indeed, may be said to be the basis of all agricultural operations. It is, therefore, a subject which, in a work like *The Book of the Farm*, demands the fullest and most careful consideration. Happily, many active minds have for years been at work in the investigation of the subject, and, as a consequence, the present generation have a fuller knowledge of it than was available to their forefathers. In the immediately preceding pages much information is given which bears upon soil fertility, but agriculturists will find it useful to likewise study the subjoined treatise prepared for this work, mainly by the late Mr R. Warrington, F.R.S., who was for some years associated with Sir John Bennet Lawes and Sir Henry Gilbert in the experimental work at Rothamsted, the matter having been revised for the present edition by Dr Bernard Dyer and others:—

By the fertility of soil we understand its capability of producing crops. A soil producing small crops we speak of as deficient in fertility, while another yielding a large average produce we speak of as decidedly fertile. It is evident, however, to every one acquainted with agriculture, that the production of large or small crops depends greatly on circumstances quite unconnected with the nature of the soil. It depends, for instance, greatly on the climate of the district, or on the character of the season. The same soil in Sweden and in the south of France would yield very different amounts of produce. The same soil on the north and south sides of a Scotch hill will have a very different value. Or, to give one more familiar illustration, a change from the east to the west coast of Great Britain will entirely alter the productiveness of a soil for many crops.

The fertility of land is thus a very complex idea, and may depend on circumstances quite unconnected with the character of the soil. This fact must always be borne in mind. In the present short article we shall speak only of those elements of fertility which belong to the soil itself: these require the co-operation of a suitable climate and season before they can determine actual fertil-

ity—that is to say, the production of crops.

The limited influence of the character of the soil on the fertility of land is easily understood if we have any acquaintance with the facts of agricultural chemistry. A wheat crop, weighing at harvest 5000 lb., contains in the corn and straw only 172 lb. of combustible constituents and 48 lb. of nitrogen, both of them derived from the soil; the whole of the rest of the crop has been derived from the air and rain. For the wheat plant to assimilate to itself the carbon of the atmosphere, and to form starch, fibre, and albuminoids, it is necessary that the energy of sunlight should be received by the plant: the vigour of the plant, in fact, mainly depends on the supply of light and heat during the months of active growth. The amount of produce, thus, in most cases, depends more on the character of the season than on the composition or condition of the soil.

Physical Condition of the Soil.

Fertility is dependent, to a considerable extent, on the physical condition of the soil. The particles of a soil must be neither too coarse nor too fine. A gravel can never be fertile, although the stones composing it may possibly contain an abundance of plant-food. A pure clay would be equally unsuitable as a soil. For a soil to be really fertile it must be porous, and freely allow the movement of water and air within it; but the particles of the soil must be fine, and exposing therefore a large surface; they must also be sufficiently close together for the soil to retain, as in a sponge, a considerable amount of water. A favourable mechanical condition is frequently confined to the surface-soil, but in very fertile soils a deep tilth will always be found. The physical condition of a soil is fortunately a point on which the farmer's practical skill can have great influence: he can, to a considerable extent, consolidate it or pulverise it at pleasure. Who does not know the amazing difference in the growth of a crop of barley, or turnips, according to the kind of tilth which the farmer obtained at the time of sowing! Any lumps in a soil

are clearly useless to the plant. Roots do not penetrate them; they neither furnish plant-food nor moisture. In a finely pulverised soil delicate roots spread with freedom, and every particle of soil is in a condition to yield to the roots the plant-food which it may contain.

There are a few points relating to the physical condition of soils which should be thoroughly understood by every farmer. The cementing ingredients in a soil are clay and humus. A sandy soil is made firmer and its power of retaining water increased either by claying, or by applications of farmyard manure, or by the cultivation of grass or clovers, or by any treatment in which the vegetable matter in the soil is increased.

Clays, on the other hand, are made more open and pulverulent by applications of chalk or lime, the effect of which is often quite surprising. The lime or chalk forms some chemical or physical compound with the finer particles of the clay which causes them to "flocculate" or aggregate into large particles, rendering the soil at once more "open." The effect of lime on clay may be readily demonstrated by shaking up some clay with water in two bottles, and adding to one of them a little milk of lime. In the latter, the clay will be coagulated and will fall as a precipitate, whereas in the other bottle much of it will remain for a long time in suspension. An increase in the amount of humus will act in the same direction; and frost is also a most powerful disintegrating agent.

Relation of Soils to Water.

Some facts concerning the relation of soils to water should also be remembered. The ingredient of soils which has the greatest power of retaining water is humus; next to this stands clay. In a time of drought the soil loses least water when the surface is in a rough open condition, as under these circumstances the subsoil water cannot reach the surface by capillary attraction. Sometimes, however, as when sowing turnips in very dry weather, it is necessary to make use of any water remaining beneath the surface. To effect this the

farmer must obtain a fine tilth, and finally consolidate the land by rolling: capillary attraction will thus be established, and probably enough moisture brought to the surface to germinate the seed.

In spring time, and generally in cold seasons, the warmth of the soil will have a great influence on its fertility. The warmth of a soil will be less in proportion to the amount of water which it contains. One of the great benefits of draining is to increase the temperature of cold soils, and thus determine an earlier growth in spring.

Plant-Food.

The fertility of soil depends in great measure on the amount and condition of the plant-food which it contains. The soil furnishes the plant with all its incombustible constituents, and also with nitrogen. The ash of plants always contains six substances, which, described by their most familiar names, are—potash, lime, magnesia, iron, phosphoric acid, and sulphuric acid. These six ash constituents, and nitrogen, are all absolutely essential for plant-growth, and the absence of any one of them would deprive a soil of fertility. Besides the six substances just mentioned, the ash of plants contains soda, silica, and chlorine; these are often present in the plant in large quantity, but they are far less important to plant-life than the six first mentioned.

Of the seven essential elements of plant-food which are derived from the soil, four—lime, magnesia, iron, and sulphuric acid—are usually present in the soil in sufficient quantity. The attention of the agriculturist has, therefore, chiefly to be directed to the remaining three—nitrogen, phosphoric acid, and potash. The various degrees of fertility possessed by different soils depend, to a large extent, on the amounts of these three substances present in the soil, and on their state or condition, as suitable or otherwise, for assimilation by crops.

Sources of Fertility in Soil.

The phosphoric acid, potash, and other ash constituents of plants which are found in soils, are derived from the rocks from

which the soil has been formed. The nitrogen of the soil has, on the contrary, been originally derived from the atmosphere. The origin of soil is to be traced to the gradual disintegration of rocks—the work of frost, of simple chemical agents, as water and carbonic acid, and the action of vegetation. The first vegetation would be of the scantiest description, and consist of extremely simple organisms; these would derive the small amount of nitrogen they would require from the ammonia and nitric acid of the rain and the ammonia of the air, and to some extent, no doubt, from free atmospheric nitrogen. The decay of these organisms would furnish the beginning of a vegetable soil, containing nitrogen and carbon. Gradually the disintegration of the rock, and the formation of a soil containing nitrogen, would reach the stage at which the herbage of a pasture or forest-trees would find a suitable feeding-ground. The soil might then remain in a condition of natural vegetation till broken up by man, and devoted by him to arable culture.

Many soils have not been formed in

the places where we now find them, but have been brought to their present position by the washing of higher rocks by rain, or by the transporting power of rivers and floods. In this manner soils may be produced which contain carbon and nitrogen (the remains of vegetable matter) throughout a great depth. The most fertile soils have usually been formed by the transportation and accumulation of soil which had already attained great fertility; the deep rich soils of river-valleys have clearly such a history.

Distribution of Plant-Food in Soils.

As the nitrogenous matter of soils is derived from the remains of previous vegetation, it naturally follows that it is chiefly found at the surface. Frequently the subsoil is sand or clay, containing very little nitrogen, while the top 6 or 9 inches are of an altogether different texture, dark in colour, and containing a considerable amount of nitrogen and carbon. In an arable soil, and in an old pasture soil, at Rothamsted, there were found at different depths—

	ARABLE SOIL.		OLD PASTURE SOIL.			
	Nitrogen.		Nitrogen.		Carbon.	
	In 10,000 lb.	Per acre.	In 10,000 lb.	Per acre.	In 10,000 lb.	Per acre.
	lb.	lb.	lb.	lb.	lb.	lb.
First 9 inches . . .	13.8	3507	24.7	5,336	337.7	73,079
9 to 18 " . . .	7.2	1679	7.2	1,916	76.4	20,223
18 to 27 " . . .	5.6	1272	4.4	1,329	37.3	11,346
27 to 36 " . . .	4.0	886	4.3	1,290	28.9	8,772
36 to 45 " . . .	3.3	772	3.8	1,231	23.1	7,464
45 to 54 " . . .	3.1	773	3.6	1,208	21.3	7,110
Total, 54 inches		8889		12,310		127,994

The concentration of both nitrogen and carbon in the first 9 inches is here very apparent.

The distribution of the important ash constituents in a soil is somewhat different. When a soil has been unmanured the phosphoric acid generally shows accumulation at the surface, but to a less extent than the nitrogen. Potash shows still less accumulation at the surface, and is sometimes more abundant in the

subsoil. In a soil which has been well manured, the tendency to accumulation at the surface is naturally increased. Lime and magnesia are generally more abundant in the subsoil than at the surface.

Nitrogen, Phosphoric Acid, and Potash in Soils.

The proportion of nitrogen, phosphoric acid, or potash in a soil is generally

very small. Thus the arable soil above mentioned, though of fair fertility, contained in the first 9 inches barely 1.4 lb. of nitrogen per 10,000 lb. of soil; and soils may be of very fair fertility which contain only 15 lb. of potash and 10 lb. of phosphoric acid per 10,000 lb. of soil. These quantities, however, become really considerable when we remember what they amount to *per acre*. Nine inches of soil when dry will weigh somewhere about 3,000,000 lb.¹ A soil, therefore, of the description just assumed, would contain in 9 inches 4200 lb. of nitrogen, 4500 lb. of potash, and 3000 lb. of phosphoric acid on an acre. In soils of renowned fertility, the quantities of plant-food will be much more considerable. Thus C. Schmidt found in 10,000 lb. of the black earth of South Russia—

	Nitrogen.	Phosphoric Acid.	Potash.	Lime.
	lb.	lb.	lb.	lb.
First 7 inches	31	15	220	162
At 28 "	17	14	220	413
At 105 "	5	11	214	557

The proportion of nitrogen and potash is here very exceptionally high; the richness of the soil in these constituents, also, extends to a considerable depth. Deep soils with such a composition have an almost inexhaustible store of fertility.

The quantities of nitrogen, phosphoric acid, and other elements of plant-food contained in a soil, indicate, however, very imperfectly, its degree of fertility. Not only the quantity but also the *condition* of these elements has to be taken into account. An acre of soil may contain near the surface several thousand pounds of nitrogen and several thousand pounds of phosphoric acid; and yet the application of 50 lb. of nitrogen or nitrate of soda might double the wheat crop, and 50 lb. of phosphoric acid as superphosphate might double the turnip crop. Such facts would plainly show that, however large might be the quantity of nitrogen or phosphoric acid in the soil, the crops did not actually find enough *available for their use* without the aid of manure.

¹ The true soil of the fields referred to in the preceding table weighed less than this, owing to the great bulk of stones present.

Humus.

We have seen that the nitrogenous matter found in the surface-soil is a residue from the decay of a previous vegetation. The nitrogen in this vegetable matter is in combination with a large amount of carbon; and in its original condition it is unfit to serve as food for crops. This nitrogenous vegetable matter is attacked in the soil by a number of agents—insects, worms, fungi, and bacteria—which, in various ways, effect the oxidation of the carbon, which is given off as carbonic acid gas, while the nitrogen remains in the soil in simpler combinations.

The black, nitrogenous, humic matter of soils is a substance admirably fitted to serve as a store of nitrogen within the soil. Only slowly acted on by water, it is not liable to be removed by excessive drainage; while by the natural processes of oxidation and hydration within the soil, a portion of the nitrogen is yearly converted into substances fitted to serve as plant-food. The most important result of the oxidation of humus is the production of nitrates. This work is accomplished by minute vegetable organisms or bacteria. No doubt a number of species are concerned in the gradual steps of decomposition which result in the conversion of the nitrogen of the humus into ammonia which must precede actual nitrification. The conversion of the ammonia into nitrates is effected in two stages by two kinds of bacteria, one of which converts the ammonia into nitrites, while the other completes the process by converting the nitrites into nitrates. The whole of these processes together are often collectively called "nitrification."

Production of Nitrates in Soils.

As upon the production of nitrates the fertility of a soil greatly depends, we must for a moment glance at the conditions which are requisite for this operation to occur. The production of nitrates is favoured by aerating the soil, by ploughing, stirring, and cultivation of all kinds. It is increased when the soil becomes wet, provided that there is free drainage. It is greatly increased by a rise of temperature, and is far more

active in summer than in winter. Nitrification will not take place in a sour soil, as a peat-bog. To such a soil chalk or a moderate dose of lime must be added before nitrification can occur.

A bare fallow affords the greatest opportunity for the accumulation of nitrates in the soil. The results of analyses of soil and of drainage-water have shown that not less than 80 lb. of nitrogen, per acre, are ordinarily converted into nitrates during a season of fallow (about fifteen months) on the farm-land at Rothamsted.

Solubility of Phosphates and Potash in Soils.

We have seen that only a very small part of the nitrogen in a soil is immediately available to a crop. The same may be said both of the phosphoric acid and potash which soils contain. Neither of the last-named substances occurs in soils in a readily soluble form. If soluble phosphates or potash salts are applied to a fertile soil, the potash and phosphoric acid are removed from solution by the soil. This fact is of great importance, as these valuable substances are thus scarcely at all removed from the soil by subsequent drainage. Potash and phosphates enter the plants chiefly through the solvent action of the feebly acid root-sap. The quantity of phosphoric acid and potash in a soil which is soluble in a weak acid may be very small. Thus Schmidt found in the Russian soil already referred to, that out of 220 lb. of potash in the surface-soil, less than 5 lb. were soluble in a cold one per cent acid, while 35 lb. were dissolved by hot acid of ten times the strength. In the same way, out of 15 lb. of phosphoric acid, 5 lb. were soluble in cold one per cent acid, and 13 lb. in hot ten per cent acid. The smallest of the quantities extracted by the chemist's acid would be much larger than a crop would be able to take up. We have then always to bear in mind that only a small proportion of the phosphoric acid and potash present in a soil is immediately available as plant-food.

It follows from what has been said that an "ultimate" chemical analysis is not a certain guide in discriminating the value of soils; the chemist can state

with certainty the total amount of nitrogen, phosphoric acid, potash, lime, &c., present, but it is less easy to give information as to the amount annually available to a crop.

Of late years chemists have for the most part adopted as an approximate measure of the "available" phosphoric acid and potash in the soil, the use of a one per cent solution of citric acid, as proposed by Dyer. The method was founded on the attempt to imitate the solvent action assumed to be exerted by the root-sap on the particles of soil adjacent to the roots, but is admittedly an empirical process, since the natural relations of plant and soil cannot be reproduced in a laboratory operation. Nevertheless, the application of the method by Dyer to a large series of the soils at Rothamsted showed that the results were closely correlated to the known manurial history and cropping yield of the various plots represented, and might be taken as measuring the present fertility of the soils as far as it depends upon available phosphoric acid and potash; and an extended application of the method to soils elsewhere, both in England, in India, and in the colonies, has confirmed the utility of the method. In the Rothamsted soils it was found that, when the soil contained .03 per cent of citric acid soluble phosphoric acid, phosphatic manuring was not required for wheat or barley, but that when only .01 per cent was present, phosphatic manure was urgently needed. As regards citric acid soluble potash, .004 per cent appeared to suffice for barley, and .005 or .006 for wheat. Wood, in applying the test to chalky soils in Norfolk, found .008 of soluble potash insufficient for barley, but .013 was apparently a sufficiency.

Accumulation and Exhaustion of Fertility.

Having now some elementary notions respecting the capital of fertility or store of plant-food which soils contain, we must next consider the manner in which practical agriculture influences this capital.

In the natural life of a prairie or a forest, there is no exhaustion of the fertility of the soil; all the incombustible

constituents of the plants and animals dwelling on the land are returned again to the soil after their death; the greater part of their nitrogen is also returned to the soil. The early history of a prairie or forest soil is one of accumulation of nitrogen, the annual gain from the atmosphere somewhat exceeding the annual loss from the soil. By-and-by a stage will be reached at which the amount of nitrogen in the surface-soil, and in the vegetable and animal life upon it, has become so considerable that the annual loss of nitrogen is on an average equal to the annual supply from the atmosphere. An equilibrium will then be established, which will continue till man steps in and disturbs it. There will be also under the conditions of natural vegetation an accumulation in the surface-soil of some of the ash constituents of plants, since these are taken from the subsoil by the deeper roots, and returned to the surface on the decay of the plants, or in the manure or dead bodies of the animals pasturing there.

With human agriculture two distinct sources of soil-exhaustion commence. There is, first, the destruction of the accumulated nitrogenous matter of the soil by oxidation, which commences as soon as the soil is broken up by the plough; secondly, the general exhaustion, affecting all the elements of plant-food, which is brought about by the removal from the land of the crops and animals reared on it.

The effect which the ploughing up of pasture and the continuous growth in its place of arable crops has on the nitrogenous matter of the soil is well seen in the following analysis of soil, quoted by Sir J. B. Lawes in 1883, showing the amount of nitrogen in various arable soils, and in pastures of different age, at Rothamsted:—

Nitrogen per 10,000 lb. in first nine inches of soil.

	lb.
Very old pasture	24.7
Pasture laid down in 1838	19.5
Pasture laid down in 1863	17.4
Pasture laid down in 1872	15.1
Ordinary arable land	12.4
Arable soil, wheat grown continuously 38 years without nitrogenous manure	10.0
Arable soil, roots grown continuously 27 years without nitrogenous manure	9.3

When we recollect that much of the arable land at Rothamsted was probably originally pasture, the destruction of nitrogenous matter by the arable culture of centuries becomes very evident. The slow accumulation of nitrogen which takes place during the making of a modern pasture is naturally the converse of the destruction of nitrogenous matter which takes place when ancient pasture is devoted to arable culture.

It is most important, if we are to have an intelligent acquaintance with the laws which determine the fertility of soil, that we should clearly understand the circumstances which determine the exhaustion or accumulation of nitrogen in the soil. In a bare fallow we have the conditions most favourable to the destruction of the nitrogenous vegetable matter which the soil contains; the nitrogen and carbon of this vegetable matter are oxidised in the manner already described, carbonic acid and nitrates being produced, and these nitrates are readily washed out of the soil by rain. The season in which the chief loss of nitrates in the drainage-water occurs is during the autumn and winter. In climates in which the soil is frozen during the winter months, the loss of nitrates from the soil will be considerably diminished.

When a crop is grown on arable land, the nitrates formed in the soil are taken up by the crop during its period of active growth. A wheat crop may take up all the nitrates in an arable soil between April and July, but fails to protect the soil from loss during the remainder of the year. If, on the other hand, the land is laid down with grass-seeds, the loss of nitrogen as nitrates is reduced to a minimum; the production of nitrates in the soil is diminished as the land is left unploughed, and the grass is always ready to take up and convert into vegetable matter any nitrates that may be present.

But a growing crop does something more than prevent the loss of nitrates in the drainage-water. Every crop leaves a residue of nitrogenous vegetable matter in the soil, consisting of roots, leaves, stubble, &c., and this residue is a fresh addition to the nitrogenous capital of the soil. If the quan-

tity of nitrogen in a soil is stationary, neither increasing nor diminishing, the average annual additions to the soil, in crop residues and manure, equal the average losses which the soil sustains. In nature everything tends to come to an equilibrium. If the system of cropping is bad and manuring scanty, the nitrogen in the soil will gradually fall till the annual oxidation of nitrogenous matter is equal to the annual receipt. If the treatment is changed to one of high farming, the amount of nitrogen in the soil will rise, and with this the amount of nitrogenous matter annually oxidised, till at length again oxidation equals the annual receipt.

*Leguminous Crops enrich the Soil
with Nitrogen.*

Different crops are of very different value as restorers of soil nitrogen. Foremost in this respect stand leguminous crops. Leguminous crops, as peas, beans, clovers, vetches, sainfoin, and lucerne, contain far more nitrogen than any other kind of crop grown by the farmer. Moreover, these crops have the power of restoring to the soil more nitrogen than they gather from it, since, by the aid of micro-organisms (*Bacillus radicicola*), which attach themselves parasitically to, or rather in symbiosis with, their roots, they are enabled to gather and assimilate large quantities of free atmospheric nitrogen which is converted into plant substance of the same nature as that derived from nitrates or other forms of combined nitrogen. It is the presence of these bacteria that causes the familiar wart-like nodules found on the roots of leguminous plants. To grow a crop of peas, and plough the whole into the land as manure, is a plan much used for renovating the soil in parts of the United States. The leguminous fodder crops, and especially those with deep roots, as red clover and lucerne, leave, however, so large a residue of root and leaf on the land, that the crop may be cut for hay and removed, and the surface-soil still left greatly enriched with nitrogen. On land which will grow leguminous crops, the farmer should have no difficulty in maintaining the nitrogenous richness of the surface-soil.

Soil Inoculation.

It was the work of Hellriegel and Wilfarth in 1886, followed by that of Marshall Ward (1887), of Beyerinck (1888), and of Prazmowski (1890), that established our knowledge of the leguminous root-nodule organism *Bacillus radicicola*, and its important place in the plant economy of the world. Nobbe shortly afterwards conceived the idea of cultivating the organism *per se* outside of the plant, and using the cultures for the inoculation of soils or of leguminous seeds before sowing, in order to ensure the presence, when the seed germinated, of the organisms without which the useful nitrogen-fixing partnership could not be formed. His "cultures" (introduced commercially under the name of "Nitragin") failed largely, probably on account of their being grown in gelatine, a substance which, as it already contained combined nitrogen, demoralised the bacteria, since, after having once grown in it, they would no longer act as collectors of free nitrogen. Subsequently Hiltner, and later Moore, of the Department of Agriculture at Washington (1901-1904), devised better means of cultivation by which the characteristic power of the organisms was retained, Moore's "cultures" being sent out on cotton-wool. Prof. Bottomley, of King's College, London, claimed (1907) to have devised a still better mode of growth and distribution, sending out "cultures" in powder form, prepared under conditions said to maintain the vitality and power of the organisms for a longer period under the artificial conditions necessary for distribution and use.

The inoculation of seed or soil with these artificial cultures has been attended with varying success. In many cases heavy increases in the crops grown have been recorded. The success or failure of the experiment of artificial inoculation (always presuming that the culture stock of bacilli is living and potent) must, it would appear, depend upon whether any given soil does or does not already contain a sufficient and effective supply of the organisms necessary for the due infection of the leguminous crop that is to be grown. There is reason to suppose that there are distinct varieties, if not

species, of these nodule organisms specially adapted for different species of Leguminosæ, and that these varieties are not necessarily interchangeable for all species. This may explain why lupines have sometimes been known to fail where they have never before been grown, although more familiar leguminous plants have long been locally cultivated.

Whether or not artificial inoculation for any particular leguminous crop will do good or not can probably only be determined by local experiment. It would seem probable that on land on which various leguminous crops have been long grown the organisms necessary for healthy infection will generally be found, and in such cases the expectation of good results would seem to be negative. But there appears to be room for extended investigation on the subject. Bottomley states that he has succeeded in infecting the roots of a non-leguminous plant (namely, the tomato) with *B. radicicola*. Whether the infection will result in a useful symbiotic combination akin to that formed with the Leguminosæ, and if so, whether the process will be found capable of extension to plants of still other orders in such a way as to engage them in the work of nitrogen accumulation, has yet to be seen.

Other Soil Micro-Organisms.

Apart from the bacteria which co-operate with leguminous plants to gather and fix free nitrogen, there are various other micro-organisms in the soil (notably *Azotobacter chroococcum* and species of *Clostridium*) which have been shown to be capable, either independently or symbiotically with other plants of almost as lowly growth as themselves, of fixing free nitrogen. How far action of these is sufficient to affect the nitrogen contents of the soil to a practical extent under the conditions of arable farming we scarcely know yet, but their effect is probably small compared with that of the root organisms of the Leguminosæ.

Nitrogenous Manures which enrich the Soil.

The manures which tend to increase the nitrogenous capital of the soil are

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those which contain nitrogen united with carbon, as farmyard manure, seaweed, oilcakes, &c. Salts, like nitrate of soda or sulphate of ammonia, benefit the crop and not the land; or rather, they benefit the land only through the crop, as the larger crops grown by their use leave of course a larger residue of roots, &c., in the soil. The experiments at Rothamsted afford several examples of the great enrichment in nitrogen of the surface-soil from long-repeated applications of farmyard manure or oilcake; they also show that the nitrogen of such manuring stored in the soil is but slowly transformed into a state suitable for plant-food, and that its effect is consequently spread over many years.

Oxidation in different Soils.

Before leaving the subject of the conservation of the nitrogen of the soil, we must remark that different soils will differ greatly in their rate of oxidation, and will demand, therefore, a different treatment. In a light soil, admitting a free access of air and rapid drainage, the effect of manure will be far less enduring than on a heavier soil, and great skill will be needed to maintain such land in a fertile condition. On the other hand, upon heavy soils the effect of farmyard manure will be felt over many years: on such land oxidation may be so slow that bones may almost be without effect.

Farmers have long ago recognised the distinctive treatment proper to light and heavy soils. On light, free-draining soil, the farmer will rely on green-crop sheep feeding, and organic manures, and he will use artificial manures sparingly. He should endeavour to prevent loss of nitrates by keeping his land always occupied by some growing crop. Catch-crops of rye or mustard which can be fed off, or ploughed in immediately before sowing the main cereal crops, are very advisable. On heavy land organic manures are of less immediate value, and soluble artificial manures become of more importance. The farmer endeavours to keep the land from becoming too solid, and avoids sheep treading in winter. He will act wisely, however, by following the advice already given, and keeping the land as far as possible

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always under a crop. It should be borne in mind that although autumn ploughing is excellent for improving the physical condition of clay soils, it is at the same time frequently the cause of much loss of nitrogen to the soil. The aeration caused by ploughing, and the absence of crop through the winter months, are indeed the special conditions favourable to a loss of nitrates by drainage. When ploughing can be delayed till spring there is less loss of nitrogen

in winter, and the aeration of the soil by the spring ploughing comes at the time when nitrate is needed by a young crop.

Exhaustion by removal of Crops and Stock.

We must next consider very briefly the exhaustion of fertility which is due to the removal of crops or animal produce from the land. The principal constituents of farm crops of average bulk are shown in the following table:—

THE WEIGHT AND AVERAGE COMPOSITION OF ORDINARY CROPS IN POUNDS PER ACRE.

	Weight of Crop.		Total pure Ash.	Nitrogen.	Sulphur.	Pot. ash.	Soda.	Lime.	Magnesia.	Phosphoric Acid.	Chlorine.	Silica.
	At Harvest.	Dry.										
Wheat, grain, 30 bushels	lb. 1,800	lb. 1,530	lb. 30	lb. 33	lb. 2.7	lb. 9.3	lb. 0.6	lb. 1.0	lb. 3.6	lb. 14.2	lb. 0.1	lb. 0.6
" straw . . .	3,158	2,653	142	15	5.1	19.5	2.0	8.2	3.5	6.9	2.4	96.3
Total crop .	4,958	4,183	172	48	7.8	28.8	2.6	9.2	7.1	21.1	2.5	96.9
Barley, grain, 40 bushels	2,080	1,747	46	35	2.9	9.8	1.1	1.2	4.0	16.0	0.5	11.8
" straw . . .	2,447	2,060	111	13	3.2	25.9	3.9	8.0	2.9	4.7	3.6	56.5
Total crop .	4,527	3,827	157	48	6.1	35.7	5.0	9.2	6.9	20.7	4.1	68.6
Oats, grain, 45 bushels .	1,890	1,625	51	38	3.2	9.1	0.8	1.8	3.6	13.0	0.5	19.9
" straw . . .	2,835	2,353	140	17	4.8	37.0	4.6	9.8	5.1	6.4	6.1	65.4
Total crop .	4,725	3,978	191	55	8.0	46.1	5.4	11.6	8.7	19.4	6.6	85.3
Meadow-hay, 1½ ton .	3,360	2,822	203	49	5.7	50.9	9.2	32.1	14.4	12.3	14.6	56.9
Red clover hay, 2 tons .	4,480	3,763	258	102	9.4	83.4	5.1	90.1	28.2	24.9	9.8	7.0
Beans, grain, 30 bushels	1,920	1,613	58	77	4.4	24.3	0.6	2.9	4.2	22.8	1.1	0.4
" straw . . .	2,240	1,848	99	22	4.9	42.8	1.7	26.3	5.7	6.3	4.3	6.9
Total crop .	4,160	3,461	157	99	9.3	67.1	2.3	29.2	9.9	29.1	5.4	7.3
Turnips, root, 17 tons	38,080	31,266	218	63	15.2	108.6	17.0	25.5	5.7	22.4	10.9	2.6
" leaf . . .	11,424	1,531	146	49	5.7	40.2	7.5	48.5	3.8	10.7	11.2	5.1
Total crop .	49,504	4,657	364	112	20.9	148.8	24.5	74.0	9.5	33.1	22.1	7.7
Swedes, root, 14 tons	31,360	3,349	163	74	14.6	63.3	22.8	19.7	6.8	16.9	6.8	3.1
" leaf . . .	4,704	706	75	28	3.2	16.4	9.2	22.7	2.4	4.8	8.3	3.6
Total crop .	36,064	4,055	238	102	17.8	79.7	32.0	42.4	9.2	21.7	15.1	6.7
Mangels, root, 22 tons	49,280	5,628	426	96	4.9	222.8	69.4	15.9	18.3	36.4	42.5	8.7
" leaf . . .	18,233	1,654	254	51	9.1	77.9	49.3	27.0	24.2	16.5	40.6	9.2
Total crop .	67,513	7,282	680	147	14.0	300.7	118.7	42.9	42.5	52.9	83.1	17.9
Potatoes, 6 tons . . .	13,440	3,360	127	47	2.7	76.5	3.8	3.4	6.3	21.5	4.4	2.6

It is frequently supposed that cereal crops are among those most exhausting to the soil. A study of the table shows that this is not really the case. The grain from fairly good crops of wheat, barley, or oats, removes from an acre of land only about 35 lb. of nitrogen, 9 lb.

of potash, and 14 lb. of phosphoric acid—quantities smaller (with one exception) than those contained by any other crop mentioned in the table. The apparently exhausting character of cereal crops is doubtless due to the small residues which they leave in the soil, and to the

loss of nitrogen as nitrates which the soil frequently suffers from autumn and winter rains after the crop has been removed from the land. The straw of cereal crops usually contains a rather considerable amount of potash; the sale of straw from land naturally poor in potash is therefore unadvisable, unless manure containing potash is also purchased for the farm. Poverty in potash is, however, not a common fault of soils.

A crop of grass hay removes generally a greater quantity of valuable constituents from the soil than a cereal crop, and this is particularly the case in respect of potash. The exhaustion of potash is of greater importance, as the short roots of grass limit its power of taking potash from the subsoil. Potash manures are often of great service on meadows mown for hay.

Root crops, if removed from the land, are by far the most exhausting to the soil of any crops grown by the farmer. The amount of nitrogen they contain is very considerable, and the quantity of potash extremely large. As the growth of roots extends much later into the autumn than is the case with cereal crops, they are able to make use of nitrates formed in the soil long after the cereals have been removed. Root crops are thus economical so far as their demand for nitrogenous manure is concerned.

The leguminous crops remove very large quantities of nitrogen and potash from the soil; the nitrogenous residue of roots, leaves, and stubble left in the soil is, however, so considerable, that in practice they rank as agents for enriching the surface-soil with nitrogen.

The exhaustion of fertility by any crop depends of course on whether it is removed from the farm. The figures in the table on previous page plainly show that the sale of cereal grain removes a far smaller quantity of the elements of plant-food than the sale of hay or roots. The sale of straw will remove a considerable amount of potash, but will not else be productive of exhaustion to the soil.

When the sales from the farm are confined to corn and meat, the annual loss of phosphoric acid from the farm is but small. In a four-course rotation

with average crops this loss would be generally covered by the use of only $1\frac{1}{2}$ cwt. of superphosphate per acre for the root crop. The loss of potash would, in the case assumed, be still less, and on a clay soil, containing considerable amounts of potash in the subsoil, might be safely neglected. Potash can be applied as potash salts, but is more usually restored to the land by the consumption of purchased food.

The annual loss of nitrogen by the sale of corn, and during the consumption of hay and root crops by stock, is much more considerable than the loss of phosphoric acid or potash. The amount of nitrogen retained by an animal from its food, and sold as meat, is but small, but the loss of nitrogen from the manure may be very great. The smallest loss of nitrogen will probably occur when the hay or root crop is consumed on the land during showery weather; on a dry soil there is sure to be loss of ammonia. In feeding roots to sheep, it is a good plan to let the plough follow the sheepfold as soon as possible.

When food is consumed at the home-stead, and farmyard manure is made, there must be a good supply of litter. In Germany considerable use is made of powdered gypsum or kainit for preventing loss of ammonia in stables. One pound of either per horse per day, sprinkled on the litter, is said to be a sufficient quantity. Farmyard manure must be protected from heavy rain. But it should, on the other hand, not be allowed to become dry. A failure in these conditions will increase the loss of nitrogen.

As a set-off to the losses of nitrogen in farm practice, we must remember that the atmosphere supplies some quantity every year. The amount of ammonia, nitric acid, and organic nitrogen in the rain does not apparently exceed 4 lb. to 5 lb. per acre per annum, but there is, doubtless, a still larger amount directly absorbed from the atmosphere by soil and crop. What the total supply from the air may amount to we cannot say. It is clearly not enough to prevent the exhaustion of land suffered to lie fallow, or from which cereal or root crops are regularly removed without the employment of nitrogenous manure; but it is

apparently sufficient to maintain the nitrogen of the soil undiminished in the case of permanent pasture, and in the case of certain rotations on poor heavy land, when the amount of nitrogen removed is limited by the consumption of straw and green crops on the farm.

We must not leave the subject of the exhaustion of land by crops without pointing out that the farmer has the power, by varying his rotation, to alter at will the amount of this exhaustion. Thus the conversion of a four-course rotation into a five-course, by keeping the land in grass and clover seeds for two years, would have a distinct effect in increasing the amount of nitrogen in the soil.

The amounts of nitrogen, phosphoric acid, potash, and some other elements of plant-food, which are removed from the farm by the sale of animal produce, are shown in the following table:—

ASH CONSTITUENTS AND NITROGEN IN
1000 LB. OF VARIOUS ANIMALS AND
THEIR PRODUCE.

	Nitro- gen.	Phos- phoric acid.	Potash.	Lime.	Mag- nesia.
	lb.	lb.	lb.	lb.	lb.
Fat calf . . .	24.64	15.35	2.06	16.46	0.79
Half-fat ox . .	27.45	18.39	2.05	21.11	0.85
Fat ox . . .	23.26	15.51	1.76	17.92	0.61
Fat lamb . . .	19.71	11.26	1.66	12.81	0.52
Store sheep . .	23.77	11.88	1.74	13.21	0.56
Fat sheep . . .	19.76	10.40	1.48	11.84	0.48
Store pig . . .	22.08	10.66	1.96	10.79	0.53
Fat pig . . .	17.65	6.54	1.38	6.36	0.32
Wool, unwashed	73.00	1.00	40.00	1.00	0.70
Milk	5.92	2.00	1.70	1.70	0.20

It will be noticed that sheep, for the same weight, contain less phosphoric acid than oxen. A pig removes less of all the valuable constituents than an ox or sheep. A fat animal contains, for its weight, less nitrogen and phosphates than a lean one. The milk of one cow (600 gallons) will, if sold, remove in a year 36 lb. of nitrogen, 12 lb. of phosphoric acid, and 10 lb. of potash.

Restoration of Fertility by Manuring.

Having thus briefly considered the influences of cropping on the fertility of soil, and the losses of fertility arising from the sale of crops and of animal produce, we must, in the next place, speak still more briefly of the restoration of fertility by manuring.

The general manuring effected by the application to the land of the manure resulting from the consumption of crops by stock will, of course, only partially replace the loss of fertility by the soil; the sale of corn and animal produce, and the waste of nitrogen in the preparation of manure, and by winter drainage from the soil, will still remain as annual sources of loss. On heavy land in poor condition, the losses of nitrogen by sales, by drainage from the soil, and in the preparation of manure, may be so moderate, that the whole may be covered, or nearly covered, by the atmospheric supply; but on fertile soil, where good crops are produced, the quantity of nitrogen sold, the loss in dealing with a large bulk of manure, and the loss by drainage from a soil rich in nitrogen, will amount to a total far in excess of the supply from the air, and demanding, therefore, the use of additional manure if high fertility is to be maintained.

We need not now discuss the theories of manuring long ago propounded by Liebig. Facts have taught both the farmer and chemist that it is needless to attempt the restoration of *all* the elements removed by the crop from the soil, since with some of these the soil is abundantly provided. Neither must manuring be confined to the substances contained in the ash of crops. The supply of nitrogen to the soil is indeed frequently more necessary than the supply of ash constituents if we desire to restore a lost fertility.

Phosphatic Manure.

The secret of economical manuring is to apply the manure required on the farm to that crop which most stands in need of it, and in no greater quantity than will produce a profitable result. Thus the farmer will apply the phosphates which his land requires to the turnip crop, because this crop will show the largest return for phosphate. He will also, if he wishes to avoid waste, ascertain, *by trial on his own land*, what is the largest quantity of superphosphate that will give a paying result. It will frequently be found that any quantity exceeding 3 cwt. per imperial acre, drilled with the seed, produces no profitable

result. In such a case, to use more than this is clearly waste. But in some localities, especially in Scotland and the North of England, much larger dressings are found necessary to get the best crops.

Nitrate of Soda.

Nitrate of soda is a manure of the greatest value to a farmer, more especially for cereal crops and mangels. When the nitrates naturally formed in the soil have been in great part washed out by winter rains, a small spring dressing of nitrate of soda restores at once the lost fertility. If a considerable dressing of nitrate is to be employed, it should generally be accompanied by a dose of phosphate. Any amount of nitrate in the soil which is in *excess* of the other ingredients of plant-food is of no advantage to the crop. Sulphate of ammonia acts more slowly than nitrate of soda. The ammonia is converted into nitric acid in the soil. The relative permanency of the different nitrogenous manures, and their influence on the nitrogenous contents of the soil, have been already noticed (p. 325).

Potash.

Potash manures can now be purchased at a moderate price. On certain soils they produce a great effect on pasture, grass-seeds, potatoes, and roots. Potash salts are therefore worth a careful trial by every farmer.

Retention of Manures.

On soils containing clay, applications of potash have a permanent value, the manure unused by the crop remaining in the soil available for other crops. Phosphates are also firmly retained by a fertile soil. The phosphate of lime applied in the manure changes, however, in the soil to phosphate of iron, and becomes less valuable as plant-food. Fresh applications of phosphatic manure are thus continually demanded for the turnip crop.

The power of retaining phosphoric acid, potash, and ammonia, differs with different soils: a high retentive power is requisite for economic manuring and the accumulation of fertility. A soil having a high retentive power will, other things being equal, be naturally more fertile than one having less power

of retention. The ingredients of the soil which retain potash and ammonia are clay, humus, and oxide of iron; oxide of iron and clay retain phosphoric acid. Phosphoric acid is more firmly held than potash or ammonia, and occurs only in minute quantity in drainage-waters.

Manurial Residue of Foods.

A common mode of increasing the fertility of land is by the use of manure obtained by the consumption of purchased food. The value of such manure depends—1. On the composition of the food; 2. On the character of the animal consuming it; 3. On the treatment of the manure before it reaches the land.

A food rich in nitrogen, phosphates, and potash, will give a far more valuable manure than a food poor in these constituents. Indeed, as a rule, the richer is the diet in these constituents, the smaller will be the proportion of them retained by the animal. The following table shows the quantity of nitrogen, potash, and phosphoric acid contained in 1000 lb. of ordinary cattle-foods:—

MANURIAL CONSTITUENTS IN 1000 LB.
OF ORDINARY FOODS.

	Dry matter	Nitro- gen.	Potash	Phos- phoric acid
	lb.	lb.	lb.	lb.
Cotton-cake (decorticated)	918	70.4	16.3	31.5
Rape-cake	887	50.5	13.0	20.0
Linseed-cake	883	43.2	12.5	16.2
Cotton-cake (undecorticated)	878	33.3	20.0	22.7
Linseed	882	32.8	10.0	13.5
Palm-kernel meal (English)	930	25.0	5.5	12.2
Beans	855	40.8	12.9	12.1
Peas	857	35.8	10.1	8.4
Malt-dust	905	37.9	20.7	18.1
Bran	860	23.2	15.5	27.2
Oats	870	20.6	4.9	6.9
Wheat	877	18.7	5.3	8.1
Barley	860	17.0	4.7	7.8
Maize	890	16.6	3.8	5.9
Clover-hay	840	19.7	18.6	5.6
Meadow-hay	857	15.5	16.0	4.3
Bean-straw	840	10.1	19.4	2.9
Wheat-straw	857	4.3	6.3	2.2
Barley-straw	857	5.6	10.7	1.9
Oat-straw	857	6.4	16.3	2.8
Potatoes	250	3.4	5.8	1.6
Mangels	115	1.9	4.6	0.7
Swedes	107	2.4	2.0	0.6
Carrots	150	2.2	3.0	1.1
Turnips	80	1.6	2.9	0.8

These figures show that oilcakes, beans and peas, malt dust and bran, are the most valuable foods for the production of rich manure. Hay and straw are characterised by containing a considerable amount of potash. The cereal grains and roots contain nearly the same quantity of nitrogen in their *dry substance*, the roots supplying the most potash. The poorest manure is that yielded by wheat-straw.

The proportion of nitrogen, &c., which passes into the manure depends, of course, on the amount retained by the animal. The same food supplied to different animals will yield manure of very different values. A ton of corn consumed by a milking cow or fattening pig will produce manure of much less value than if given to a working horse. When, as in the latter case, there is no increase of animal produce during feeding, the quantity of nitrogen, phosphates, and potash in the manure will be correspondingly greater.

Lastly, the value of the manure will much depend on the manner in which it is preserved.

Lime.

We have not spoken of lime as a manure, because it is not generally, like other manures, intended to serve as a plant-food. As will be shown in the section dealing with "Liming Land" in this volume, an application of chalk or lime often greatly increases the fertility of a soil; but it does this chiefly by improving its physical and chemical condition. Lime especially acts by attacking the nitrogenous organic matter of the soil, and rendering it more available as plant-food. Lime is invaluable in reclaiming peat.

Valuation of Unexhausted Manures.

Before concluding our brief summary of the chief points which determine the fertility of soil, some reference will probably be expected to the difficult question of the valuation of unexhausted improvements. Under certain circumstances an outgoing tenant can now claim compensation for past expenditure which has resulted in an increase of the fertility of the land. In considering any such claim, it should always be recollected

that the only real proof of increased fertility is the fact that better crops can be grown than formerly. If this fact cannot be established, it is hard to see how any claim can be sustained. The amount of increase in the crops, and the length of time that the additional fertility of the land will probably endure, are thus points which would, if they could be fixed, determine the unexhausted value of past improvements. Such estimates are, however, attended with much uncertainty. In cases, therefore, in which the outgoer has a clear claim, either against the landlord or the incoming tenant, it is more usual to estimate what proportion of the value of each item of acknowledged improvement is unexhausted at the time of leaving. The value of such operations as draining or liming depends so greatly on the nature of the soil, that the experience already gained in carrying out these operations on similar land will be the chief, if not the only, guide in assessing a fair charge for these items of claim.

With regard to unexhausted manures something more may be said. We have already pointed out that while nitrate of soda and salts of ammonia give their effect entirely in the first year, applications of nitrogenous organic manures, as farmyard manure, sea-weed, fish, bones, or oilcakes, give only a portion of their effect in the first season of their application, and their employment may therefore become a subject of claim against the landlord or incoming tenant. The use of purchased phosphates or potash salts may also possibly become a subject of claim, as any surplus of phosphates or potash remaining in the soil is more or less available for future crops.

As nitrogenous manures are the most costly, and, on the whole, of most importance in increasing the fertility of the land, their valuation has naturally received the greatest attention. Nitrogenous organic manure is generally obtained by the consumption of food by stock. The consumption of purchased foods on the farm thus becomes a frequent subject of claim. The claim has frequently but erroneously been based on the price given for the cake or corn consumed; it is obvious, however, that the price of the food has no necessary

connection with its manurial value. A ton of wheat and of cotton-cake may be similar in price, but the latter contains nearly four times as much nitrogen as the former, and should yield a manure nearly four times as valuable.

Sir J. B. Lawes in 1860 published a table showing the estimated value of the manure obtained by the consumption of one ton of various articles of food. In 1885, Lawes and Gilbert returned to the subject, and published in the *Journal of the Royal Agricultural Society* (vol. xxi. p. 590) a table showing the estimated value of the manure from one ton of food, not only when freshly prepared, but during a series of eight years after the application of the manure to the soil. The amount of nitrogen, phosphoric acid, and potash in the manure was reckoned by subtracting from the amount in the food that which is stored up in the animal. The foods were assumed to be consumed by *fattening* animals; and it must be recollected that if the same foods were supplied to a growing animal, or to one producing milk, a larger proportion of the nitrogen, phosphoric acid, and potash would be retained by the animal, and therefore lost to the manure. The quantities of nitrogen, phosphoric acid, and potash estimated as present in the manure were first reckoned at the money value which these substances have in active artificial manures. This value is, however, clearly in excess of the true value of animal manure,—*firstly*, because the animal manure is sure to contain less than the estimated quantity of nitrogen, the manure being, in its preparation, exposed to several sources of loss; *secondly*, because the constituents of the manure, especially the nitrogen, are not in the immediately available condition which they possess in artificial manures, and have thus not an equal money value. Lawes and Gilbert, therefore, in the case of cake, corn, and roots, took one-half of the calculated full manure value, and in the case of hay and straw, one-third of the full value, as the highest figure to be used for the purpose of valuation.

This highest valuation would be awarded if the foods had been consumed in the last year, and the manure had not yet produced a crop. From

this highest valuation $\frac{1}{2}$ would be deducted if another year had elapsed, or $\frac{1}{3}$ in the case of hay and straw; and the valuation of each succeeding year would, always according to the character of the food, be $\frac{1}{2}$ or $\frac{1}{3}$ less than that of the year preceding.

To give an example: The full value of the manure from 1 ton of linseed-cake was calculated as £3, 18s. 6d. One-half of this, or £1, 19s. 3d., was taken as the fair value of the manure, if made last year, and had not yet grown a crop. The residual value of the same manure the second year was given as £1, 6s. 2d.; the third year, 17s. 6d.; the fourth year, 11s. 8d., and so on. In making this estimate of the gradual diminution in the value of the manure, it was assumed that the land to which it is applied is heavy land. On a sandy soil, and especially on a calcareous soil, the value of the manure will more rapidly disappear.

The tables of Lawes and Gilbert were revised in 1903 by Dr Voelcker and Professor Hall (the present Director of Rothamsted), who have rediscussed the whole of the question of the valuation of unexhausted manures in the light of the latest investigations at home and abroad. Their new tables and conclusions, along with notes by Dr Voelcker, will be given in the Section of this work dealing with "Food and Feeding." Their report will be found in full in vol. lxxiii. (1902) of the *Journal of the Royal Agricultural Society of England*, and may be obtained in pamphlet form as a separate publication (John Murray, London). A very full inquiry into the subject of compensation for unexhausted improvements (manures and feeding-stuffs) was also held in 1902 by a Committee of the Central Chamber of Agriculture, whose report was published in 1903 by King & Son, of 2 Great Smith Street, Westminster, at a merely nominal price.

Causes of Infertility.

In conclusion, reference must be made to some special conditions which render certain soils infertile. A soil may be "sour" from the presence of an excess of vegetable matter and water: the cure is lime and draining. A soil or subsoil sometimes contains ferrous salts, either natural to the formation, as in lias clays,

or produced by the causes mentioned as yielding "sour" soils: the cure is lime and thorough ploughing. A soil reclaimed from the sea is charged with salts; these are best removed by throwing the land into ridges and draining. When the salts are alkaline, as is the case with large districts in California and India, repeated dressings of gypsum must accompany ridging and draining.

UTILISATION OF AIR NITROGEN BY PLANTS.

There has from time to time been much discussion over the question whether or not plants are endowed with the faculty of being able to draw nitrogen from the air for their development. As has been shown at various points in this work, leguminous plants obtain large supplies of nitrogen from that source, but as to whether other plants possess any similar powers, there are sharp differences of opinion. The view of Bous-singault and Lawes, that plants do not directly absorb nitrogen from the air, is that which is generally accepted, but the opposite opinion is stoutly maintained by some, notably by Mr Thomas Jamieson, F.C.S., the Chemist of the Aberdeenshire Agricultural Research Association. The details of the discussion cannot be entered upon in this work, but in order that something may be known of the foundation of this new doctrine, it is thought well to introduce here the following notes which, at the Editor's request, Mr Jamieson prepared on his researches on the subject.

Mr Jamieson writes: "It has long been clear to many that, apart altogether from the leguminous plants, there is evidence in the behaviour of other plants that the nitrogen of the air must be somehow available to them. It is known, for instance, that turnips, like legumes, require little or no nitrogen in their manure, and yet a good turnip crop contains a very large quantity of nitrogen,—as much as would be given by 5 cwt. of sulphate of ammonia. Again, there is the evidence that cultivated land, not manured with nitrogen, but only with phosphates and potash, has its nitrogen increased by the raising of good crops. Further, we have the evidence of

forests on nearly sterile soil accumulating in their growth enormous quantities of nitrogen; and even instances of trees growing on rocks or rocky cliffs, such as in Norway, where there is no soil and hardly a trace of nitrogen available except what comes from the air.

"With this, and other such evidences in view, many felt that the nitrogen doctrine was in need of revision. The writer, in the course of many experiments, had frequent indications, and a few years ago one instance was so striking that he decided to investigate the subject, difficult and laborious though it promised to be.

"Fortunately, the experience of the best of a lifetime in agricultural investigation prevented him from taking the false step of beginning with the legumes, as among the most nitrogenous of cultivated plants, and avoiding, indeed, at the outset, all agricultural plants. Had he gone to such plants as others may have done, failure would probably have been the result, but happening to have, many years before, investigated several weeds, he was guided to several wild plants whose nitrogenous and other characters seemed likely to lead to a solution.

"On examining by the microscope the well-known weed called *Spargula* (Spurrey or Yarr), it was found not only that it was covered with hairs, but that these hairs were of a distinctive character, jointed like a finger, the upper section, and the upper section only, containing a greenish matter like chlorophyll. The question at once arose, What is the function of these hairs? They had of course been seen by botanists, but no special function was ascribed to them, or proved. Studded freely over the leaf as these hairs were, they were there, no doubt, for a definite purpose. Hoisted up as they were into the air, it seemed probable that they had a relation to the air. As green matter is associated with activity in all plants, and separated from the air as this green chlorophyll-like matter was by the thinnest of films, it seemed probable that these were actually the organs for absorbing nitrogen. If so, they should show its presence by containing nitrogen in a more or less conspicuous quantity, in the form that

nitrogen always takes in plants—viz., albumen. Applying the well-known chemical tests for albumen, not only was albumen found in conspicuous quantity—i.e., in greater quantity than was shown by any other part of the leaf—but it was found that the quantity varied at different stages of growth, the youngest hairs containing none, the older ones showing a gradually increasing quantity, until they became gorged, when the albuminous matter was observed to be streaming downwards (instead of upwards as it would do if it came from the root) and passing thus, as well as by side channels, into the main structure of the plant. Unless there was any other function proved for these hairs, the solution seemed already so far obtained. It remained only to ascertain their presence on plants generally.

“Other plants were examined in succession. No little difficulty was experienced until it was known where, and at what stage of growth, the hairs were to be found. Frequently the hairs were not so easily found as in *Spergula*, because they occur on different parts (thus, on chickweed, they occur not on the young leaflet but on its stalk). But, in every case, after more or less examination, the same hairs were found on every dicotyledonous plant—i.e., essentially the same, by being, as a rule, more or less jointed, and having the greenish part, with more or less albumen, and ultimately conspicuously charged with albumen; but the hairs showed great variety of form and number, and frequently (as in cereals) were reduced to a rudimentary character.

“It was only when cultivated plants were taken, in which the characters are more or less altered by cultivation, and in which the leaves are fleshy, that any difficulty was ultimately found, and the difficulty was increased by the fact (which was ascertained only in progress of the investigation) that the hairs are found chiefly on the very youngest leaflets just as they are emerging from the bud, and that after having performed their function by providing the requisite quantity of nitrogen to the plant, they are absorbed into the leaf.

“Many plants were examined, including no less than thirteen botanical families,

and in every case the hairs, or a modification of them, suited to absorb nitrogen, were found. But an important fact was brought out—viz., that all plants are not equally endowed with the power of absorption. That especially the cereals and grasses are very deficient in this power, the means of absorption being modified from a well-developed jointed hair to a mere attenuation of a part of the leaf at its early stage,—a fact which it will be seen at once supports the function performed by the special hairs, and at the same time explains how cereals and grasses have to be provided with nitrogenous manures, whereas other plants, that are fully provided with them, such as turnips and legumes, require no nitrogenous manure, or only the minute quantity necessary to give a vigorous start by which the absorbing organs will be plentifully formed.

“In the following year most unlikely plants were taken, such as forest trees, including hard needle-leaved pines, and there again the hairs were in every case found, although some time was occupied in ascertaining on what particular part they were formed. On the elm, for instance, they occur not on the leaflets at all, but on the bud scales.

“Amongst objections raised in this country to the published results of these trials, the strongest was that no *weight* evidence was given indicating that there was an increase in weight of nitrogen that could have no source but the air, and the desirability of adding such gravimetric evidence led to a number of strictly controlled trials being made under more natural conditions than those that characterised the trials of Boussingault and Lawes, and by which no increase of nitrogen had been shown. These improved trials brought out very clear evidence of an increase in weight of nitrogen in each case, the details of which have been fully given in the Report of the Agricultural Research Association of Aberdeen for 1906. Happily also one or two of these trials were such that any one could verify them without any scientific skill, but merely with the application of scrupulous care. Nor does it even require analysis for proof, because the proof is self-evident.

“This trial consists in the use of an

aquatic plant, such as the *Azolla Caroliniana* (it may be obtained from T. S. Ware, Ltd., Feltham, Middlesex). A few of these minute plants placed in water with the addition of a sprinkling of phosphate and potash, but containing no nitrogen, and the water kept in a healthy state by periodic renewal, produce a very large mass of healthy plants. Now it is known that no plant whatever exists without containing albumen, and unless, therefore, these plants were monstrosities by containing no albumen, it becomes obvious that they have absorbed their nitrogen to form the albumen from the air, as no other source of it is available but the water, the traces of nitrogen in which are infinitesimal. In the actual experiments the trace of ammonia in the water was accurately determined, as well as the nitrogen in the plants grown, and they were sheltered from any accidental conveyance of ammonia, or dust, by being grown under double-glass protection. These precautions, however, are unnecessary for the unscientific experimenter, but it is fortunate that such a simple method of assurance is at the command of all.

"In addition to these trials with aquatic plants, however, non-aquatic plants were grown, both in exhausted soil and in distilled water, under strictly controlled conditions, charging the plant with every trace of nitrogen that was available for it, and crediting it with the nitrogen found in the plant, or left unused in the soil or water, and *in each case a distinct gain of nitrogen was found* in the plant that had no possible source but the nitrogen of the air.

"As in these trials only single plants, or a limited number of plants, could be used, the quantity of nitrogen absorbed could not be great, but the principle being established, an effort was made in the following year to grow a larger quantity of plants under conditions satisfactorily controlled, and *in each case a*

substantial increase of nitrogen was obtained.

"Placing all these facts alongside results which had been obtained by Ville and Atwater, one can have no reasonable doubt that nature provides plants with the power of absorbing by their leaves the nitrogen that is essential for their natural growth (though in the case of certain plants insufficient for the large growth or cultivation), just as she provides carbonic acid by the air and water by the soil. Conviction of the accuracy is got by knowing that we have now a solution that is not contradicted by common-sense and ordinary observation, but that is in harmony with practice, with experiments, and with a general consideration of nature's provision and methods.

"The practical benefit of the faculty thus claimed for certain plants of being able to directly absorb nitrogen from the air lies in the possibility assured of greatly lessening, if not altogether avoiding, the necessity of applying nitrogenous manure, which constitutes the larger part of the farmer's manure bill. Possessed of the knowledge that plant leaves absorb nitrogen, the farmer has to consider what leafy plants he can grow and plough into his soil either within or in intervals of his rotation. Already, without interfering with his rotation, he can take advantage of the knowledge by not removing a leaf of his turnip crop from the ground, but carting home only the bulbs. These leaves ploughed in will go far to secure a good oat crop the following year without nitrogenous manure. Then he may enrich his soil nitrogen by sowing clover with his lea corn; also by sowing more clover than usual (and especially white clover) in his usual grass-seed mixture; again, after an early harvest, by ploughing the stubble and sowing rape, &c., to be ploughed in in spring. Every farmer will take whatever plan suits his system best to grow and plough in as much leafy matter as possible, and experience will guide him both as to the plan and the plant to adopt."

IMPROVING WASTE LAND.

In recent times little has been done in the way of the reclamation of land. In most parts of the country, indeed, the limits of advantageous reclamation have been nearly reached; in some cases they have even been exceeded. Still there are, no doubt, considerable areas of land which might be reclaimed with advantage.

It must not be forgotten that, in our tight little islands, where the town population keeps on increasing, the proportion of farm land is as steadily diminishing, by the encroachment of urban communities. Half a million acres, it is estimated, have been diverted during the last twenty years from agricultural to residential or industrial uses.

Of course the effect of this tendency is neither felt nor fully appreciated at a time when we have more land lying unproductive in the United Kingdom than is comprised in the entire kingdom of Belgium; but it is bound to make itself felt some day. In many counties as much as 90 per cent of the total surface is under cultivation; in other counties the proportion of cultivated land is not more than 6 or 7 per cent, although the grazings in some of these cases amount to more than 70 per cent. Making all allowances for variations of climate within the confines of the British Isles, and for altitudes beyond profitable cultivation, and rugged surfaces which are unsuited for any kind of cultivation, there is yet a large area of improvable land within our borders.

The probable extent of unreclaimed peat bogs in the United Kingdom is not less than 5,000,000 acres, of which 2,830,000 acres are in Ireland. It is believed by many that with various industrial uses for peat, the main portion of these peat lands will sooner or later be brought under cultivation.

But beyond the confines of our present land surface, it is estimated by various authorities that over 2,000,000 acres of land of the most fertile character might be reclaimed from our numerous firths, estuaries, and shallow tidal basins, including Crown foreshore rights. More-

over, our warp lands could be largely increased.

It is still more incumbent, however, to make the most of the land we have, and a great deal yet remains to be done in this direction,—in draining wet soils of all kinds; in improving peat, clay, sand, and chalk soils by admixture, liming, and otherwise; in deepening the staple of cultivated lands by trenching and subsoiling; and in making full use of the fertilising rain, and exercising a wise control of soil moisture.

Although drainage is the preliminary to all land improvement, the extent of wet land in the United Kingdom that has never been drained, or is in need of re-draining, is appalling. Notwithstanding all the drain-pipes that have been used since the first Land Drainage Act was passed in 1846, not more than 4,000,000 acres have been drained up to date by both public and private monies; while about 18,000,000 acres are still in need of draining before their full capacity for production can be brought out or even ascertained.

Throughout the British Isles vast tracts of rough uninviting land have, by the enterprise of landowners and tenant-farmers, been reduced to a useful condition for arable or pastoral farming. The cost of this reclamation in many cases exceeded £10 per acre, not unfrequently running up to £15, £20, or more, per acre.

Rules for Land Improvement.

The method to be pursued in the reclamation will of course depend very much upon the character and condition of the land to be operated upon.

The following rules, laid down by Sir John Sinclair, Bart., for schemes for the improvement of waste land, are as applicable to the present day as to the time in which he wrote:—

1. Not to put in practice any scheme of improvement without the fullest consideration, nor without the command of an adequate capital.
2. Not to begin on too great a scale,

nor until, by experience, it be found that the design is suitable to the soil, situation, and climate.

3. When the intention is to cultivate bogs or peat-mosses, not to begin cropping till at least one season after the drains are completed, and the soil thoroughly reclaimed from superfluous water.

4. To plough or delve peat-mosses in autumn, that it may first be effectually exposed to winter frosts and rains, and not to summer heat, which would harden it and prevent its decomposition.

5. Whatever is done, to do it effectually,—not to think of laying on four acres the manure necessary for three, nor the lime, chalk, &c., required for two given to one.

6. To carry on the improvement of waste lands without encroaching upon the dung necessary for the improved part of the farm; and

7. To lay down any land improved from waste, in high and bleak situations, as soon as possible into grass, and to retain it in that state as long as it is tolerably productive. For though grain and roots may be cultivated on waste lands, when properly improved and favourably situated, yet grass land pastured particularly by sheep is principally to be depended upon for improving weak soils in barren districts and remunerating the improver.¹

Scottish Example.

We have in our mind an instance of somewhat extensive improvement effected upon waste land in the north of Scotland, in which these rules were carried out to a considerable extent during the progress of the work.

Original Condition of Land.—This land before the improvements were begun consisted of heath, with patches of mixed waste land which had been at one time under cultivation. For many years the whole area of the land had been under sheep.

Steading.—The position for the steading was chosen near the centre of the land to be brought under cultivation, and at a level where all the water drained from the higher ground could be

used for driving the threshing-mill, and for other purposes.

Process of Reclamation.—The first part of the operation was laying off the land near the steading into fields of about 20 acres each. Along the boundary-lines of the fields open ditches were cut during the first year. Into these ditches the leaders for the furrow drains were made to fall, and after about 40 acres were furrow-drained, the whole was ploughed as deeply as possible. Two men followed each plough, one holding the plough and the other turning over any part of the furrow the plough left unlaidd, and marking the position of land-fast stones by means of wooden pegs.

Cropping.—During the first year very little of the land was put under crop. The only parts so treated were where the land admitted of being brought into reasonably good tilth. The rest was allowed to lie until the succeeding spring or winter, when it was again ploughed, and then made suitable for the reception of seed. In the second year the land sown with oats was put under turnips, and as time went on the turnip break was gradually increased. A second crop of oats was taken where the land was rough and the turf not decayed.

Part of the land being peat-moss, the drains were put down to the clay if practicable; but where this could not be done 5 feet was about the average depth. A considerable time was allowed to elapse before ploughing was commenced, so as to allow the drains to dry the land, and to let the boggy parts settle and consolidate.

In the course of some ten years over 600 acres were in this instance reclaimed, the entire work being done by the ordinary implements of the farm, with little extra strength, except where the land was much broken and rough, when labourers had to be engaged to fill up the holes and delve such of the roughest places as horses could go over it.

Result.—Even the first rotation of crops left the land level and fairly planted with grass. From the success in this instance one would infer that in the reclamation of land extra time devoted to the execution of the work may substantially lessen the total outlay.

¹ *Rural Cyclopædia.*

Stones.—The stones turned up were used for building dykes, forming leader drains, and making the farm-roads.

Other Methods.

In other cases, where the surface of the ground is rough and much covered with coarse grass or other growth, it requires to be brought into cultivation by other means than the plough. When the ground is the site of an old plantation, it is impossible to bring it in with the plough. When the subsoil contains a large quantity of stones, of whatever size, it may not be possible to stir it with the plough. Where much brush-wood exists—as of hazel, alder, birch, broom, and whin—the plough should not be tried.

Trenching.—To bring the land speedily into cultivation in all these cases the best method is to trench it with the spade. Spade-work is expensive, but it is effective amongst roots and stones, and the ground is put by it in so prepared a state that the succeeding operations are executed with ease and satisfaction.

Reclaiming Plantation Ground.—In trenching the site of a removed plantation, a good plan is to mark out the ground in divisions of 30 feet in breadth. Three men working together will do more and better work than each man alone, the one assisting the others when extracting the roots of the trees.

No other implement is so efficient in cutting the ramified roots of a tree as the common mattock, fig. 280, which on one arm has a horizontal cutting face, and on the other a vertical. It is used like a hand-pick, and one or both faces alternately are required to cut through a strong root. An axe would soon be blunted by the earth adhering to the smaller roots, though a large root is easier cut through with an axe than a mattock.

The roots and stools, great and small, are laid upon the surface of the trenched

ground behind the workmen, and the hollows left by them in the ground filled up, and the surface levelled.

Trenching Stony Ground.—In trenching very stony ground, the foot-pick is the most efficient implement for loosening them out of the subsoil. The crowbar or pinch is required to raise what cannot be effected by the foot-pick; and the largest boulders may have to be blown to pieces by gunpowder or dynamite. The stones are laid upon the trenched ground. In many parts stones are so numerous in the subsoil that they are not only sufficient to form the drains for the land, but that to get quit of the overplus, “consumption-dykes,” several feet in height and breadth, are built in lieu of fences. As many as 800 tons of stones have been trenched out of one acre in the county of Kincardine, in the north-east of Scotland.

Draining.—In improving the site of a plantation, or very stony ground, it should be trenched before being drained, as the cost of draining would be much increased amongst roots and stones.

Depth and Cost of Trenching.—No trenching among tree-roots and boulders should be less than 18 or 20 inches deep of the solid ground. The cost of such depth of trenching may be heavy, but then by it rough useless land is at once brought into a fit condition for cropping. Although trenching may not be the cheapest mode of making land available to the plough, it is the most pleasant and satisfactory.

Trenching may be executed at any season. To allow time for subsequent operations, however, it is best and most comfortably done in the long dry warm days of summer. Small hollows and heights should be levelled in trenching. The contractor should be bound to be always with his workmen, and the farmer should have a superintendent to overlook the work, as even the contractor may direct the men to make the trenched ground seem as high as it should be, although the solid ground has not been dug to the proper depth.

Removing Turf.—When turf is desired for any purpose, it is sometimes cut from waste land about to be improved. In many parts good tough turf is not easy to be obtained, and at all

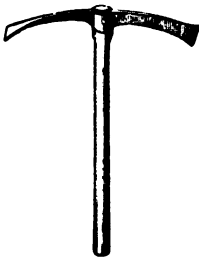


Fig. 280.—Mattock.

times it fetches a high price. A man will cut from four to six cart-loads of one ton each in a day, according to the smoothness and softness of the ground.

In almost all cases, however, the best plan will be to reclaim the land as it stands, ploughing down the turf as in the Scottish instance referred to.

Levelling Land.—Besides larger inequalities of surface, minor ones require emendation, the neglect of which renders the surface of improved arable land unpleasant to the sight. The inequalities we allude to are slight hollows, low heights running across several ridges, making one side or part of a ridge higher than the other, or part of the

head-ridge higher than the ridges, and suchlike blemishes.

Levelling-box.—An economical method of getting quit of these inequalities is with the levelling-box, fig. 281, which, according to the nature of the soil to be removed and the distance to be carried, may be worked by one or two horses. The two sides having the same depth where they join the back, are curved off to nothing at the front. It is requisite for strength that it be made of hardwood; but the common willow, from its toughness and lightness, is perhaps better adapted than any other wood for this purpose. The sole of the scoop is armed with a strong shoeing of iron,

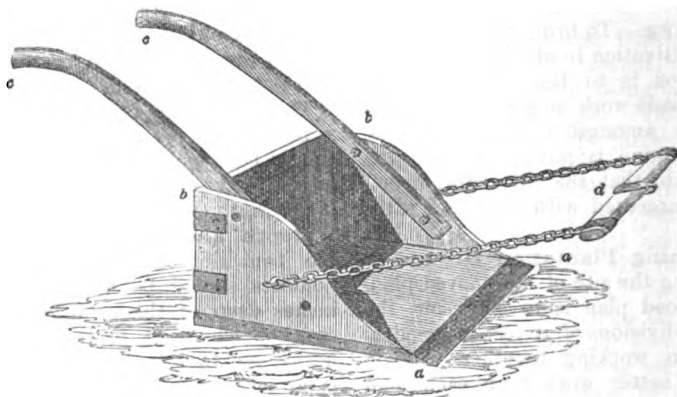


Fig. 281.—*Levelling-box, or scoop.*

b a, b a Two sides of box.
b b Back of box.

a a Sharp edge of iron sole.
c c Handles.

d Stretcher attached to the draught-chains.

terminating in a sharp cutting-edge. Two skeds or bolsters are fixed on the lower side of the sole, thinned off forward to give facility of entrance in the soil to the cutting-edge of the scoop, and upon which it runs like a sledge when filled. All the corners are strongly bound with iron plates, and the skeds upon which it runs are covered with strong sheet or hoop iron. The handles are bolted to the sides, and so fitted as to bring their extremities to a convenient distance for being held in the hands of the conductor. The draught-chains, with their stretcher, are attached to an eye-bolt or a staple on either side of the scoop.

The levelling-box is used in this manner. After the plough is first made

to turn over the soil lightly on the height to be removed, the levelling-box, worked by one pair of horses, then follows, and takes up from one end of the ploughed ground as much soil as it can contain, the conductor holding by the stilts or handles. The box is filled by the conductor allowing the handles to rise as much as that the edge of the sole shall bite the ground; and on these being drawn forward by the horses, the box is filled to any extent, when by the handles being pressed down the front edge is relieved from the ground, and the machine travels upon its skeds. On arriving at the hollow place to be filled up, the conductor, by raising up the handles, capsizes the box, and gets quit of the load of earth, the handles falling

and resting upon the stretcher; and whenever it is emptied, he levels the earth by passing the box over it.

The box is returned to its working position upon its bottom immediately, or it may move along upon its mouth, smoothing the surface till it reaches the ploughed soil, when, by a sudden pull of a rope attached to one of the handles, it regains its working position.

In all these movements the horses are not stopped, but proceed from one place to another as directed, while the box is filling and emptying in constant succession. A strong active man is required to work this implement.

Cropping New Land.—Land so drained and trenched usually bears for its first crop either potatoes or turnips—that is, if a sufficiently fine tilth can be obtained. Turnips are generally preferred to potatoes, because they may be eaten on the ground by sheep, and thus at once put the drained land into a state of comparative fertility. Where the land is ploughed, oats are a favourite crop for the first, because it assists in rotting turf quicker than green crops. Where grass has been ploughed, it is the best first crop that can be taken. Waste land broken up by the plough cannot easily be made suitable for a turnip crop, it being so rough and tough that ordinary implements have little or no effect in breaking down the furrows.

An Irish Example.

On the estate of Brockley Park, Stradbally, Queen's County, a scheme of successful improvement of land carried out by the proprietor, Mr William Young, is worthy of description here.

Original Condition of the Land.—When Mr Young succeeded to the estate, it contained a considerable area of rough, "cut-away" peat bog. Uneven in the surface, and full of stagnant water, it was in parts so soft and boggy that people or animals could not safely walk upon it. The drier portions were covered with furze and scrubby hazel bushes; while the other parts carried a strong growth of reeds and rushes. This rough land was almost worthless except as a resort for snipe and wild duck. Anxious to turn it to some good account, and to give employment

to the people, Mr Young decided to reclaim it.

Process of Reclamation.—In the first place the land was under-drained with tiles and collars, great difficulty having been experienced in many parts in getting the drains formed, owing to the extreme fineness of the sandy sub-soil. In fact, here and there it was found necessary to use boards in binding up the sides of the drains.

The land (except where it was so soft that horses could not walk upon it) was then ploughed twice—the one furrow at right angles to the other, and the large cross-cut sods were left exposed to the winter's frost. Some of the softer spots had to be cut and levelled with the spade.

First Crop.—In the following spring the ploughed land was harrowed, the roots and rougher sods burned, and the ashes spread over the surface. It was then sown with rape. The rape plants came irregularly, and the crop was not of much value. It, however, cost very little, and the action of its roots, together with the treading of the sheep that consumed it, assisted in breaking up the surface and in preparing it for further cultivation.

Second Crop.—The first crop having been eaten off by sheep, the ground was again ploughed, and, in the following June, sown with 14 lb. of rape and about a bushel of Italian rye-grass per Irish acre. A top-dressing of 3 cwt. of Lawes's turnip manure was allowed to the Irish acre; and with that treatment the land gave a good crop. This crop was also eaten off the land by sheep. It made excellent feeding the first autumn; and the sheep having had an allowance of cake upon the land, the rape and grass came up well the following spring, affording a very useful change for ewes and lambs.

Third Crop.—In May of that year it was once more ploughed up, harrowed, and drilled, and manured with about 25 tons of farmyard manure and 3 cwt. of Lawes's turnip manure per Irish acre. The main portion was planted with cabbage, but wherever the tilth could be made fine enough, turnips were sown. Both these crops were heavy and of good quality, and both were consumed on the land by sheep.

Laying to Pasture.—The land was now in a fit state for being laid down for permanent pasture. It was clean, in good heart, and wonderfully fine in the tilth. Accordingly, as soon as the turnip and cabbage crops were consumed, the land was again ploughed, and in May in the following year sown with 4 lb. of rape, 1 bushel of vetches, $1\frac{1}{2}$ bushel of perennial rye-grass, $\frac{1}{2}$ bushel of Italian rye-grass, 4 lb. of cocksfoot, 4 lb. of timothy, and 4 lb. each of alsike and white clover per Irish acre. This crop came up exceedingly well, giving a close heavy yield. In the autumn of the same year—in August and September—it was consumed on the land by sheep. The crop was so rank that much loss would have been sustained by allowing the sheep to trample upon it, and therefore they had to eat it through wooden hurdles. These hurdles, made for the purpose at Brockley Park, were light, with upright bars. They were shifted forward every second day; and with a scythe a “swathe” or “bout” of the crop was thrown up against them every morning. The sheep were allowed a moderate quantity of cake along with what they could eat through the hurdles, and thus the land, while robbed of its richness through the crops it yielded, was being recuperated by the droppings of the sheep.

Results.—The results of the treatment briefly described were eminently satisfactory. The sheep were withdrawn from the land during winter, and next spring there came up a beautiful growth of permanent pasture. No accurate account of the cost of the reclamation could be given, as the work was carried out from time to time along with other estate improvements, and with the ordinary operations of the home farm. Mr Young, however, felt certain that these crops to which we have referred fully repaid him for the cost of reclamation, and that the permanent value of the land was increased at least five-fold.

IMPROVING POOR LAND.

Another and larger portion of Mr Young's property at Brockley Park, mentioned above, consisted of poor worn-

out land. This presented difficulties of a different character, which were also successfully overcome. This land, like a great deal of the poorer and partially waste lands of Ireland, as well as extensive areas in Scotland, consists of a thin, moory, or peaty soil, with sandy or gravelly subsoil. Such land in Ireland is generally kept in what is called “pasture,” on which a few half-starved cattle drag out a miserable existence.

One great hindrance to the improvement of land of this class is that a large extent of it is of so poor a nature that when reclaimed it cannot be calculated upon as certain to prove remunerative under either arable farming or mixed farming, or as likely to carry permanent pasture with any reasonable degree of success. We therefore look upon Mr Young's system of improving and utilising such land as of the utmost public importance.

He found, in the course of some years' experience, that even after being thoroughly drained, it would not pay under any system of regular cultivation. It would not even repay him for his outlay in an ordinary course of corn and root crops. As the manure seemed to go down through the subsoil and give no adequate return, it was only when under grass that the land was really useful.

Renewing Pasture.—But seeing that the land would not carry a sufficient cover of pasture for more than two or three consecutive years without the grasses being renewed, and seeing also that a course of cropping—the usual method adopted when grasses have to be resown—always resulted in a loss (the crop being so poor as not to repay seed, labour, and manures), it became necessary to devise some other means by which the grasses might be profitably and effectively renewed. This stubborn difficulty was at last successfully overcome by the adoption of the following treatment, which we have no doubt might with much advantage be pursued in many similar cases.

When the permanent pasture on any field or division was observed to be giving way, the short sweet cover of grass which usually came up early in the season was at once eaten down by sheep, and then the land (that is to say, the

field or portion giving way) was ploughed up in the first week of June, and immediately sown down with 10 lb. of rape and 1½ bushel of Italian rye-grass per Irish acre. It was at the same time top-dressed with 3 cwt. of superphosphate and 2 cwt. of Lawes's special manure per Irish acre, the value of this doze ranging from 35s. to 40s. per Irish acre. The rape and rye-grass generally came up rapidly, and were eaten down by ewes and lambs about the middle or end of August. During winter the land was left clear, and early next spring it again presented a nice rich cover of rape and rye-grass, which was once more eaten down by ewes and lambs.

In June of that year it was ploughed up as in the previous year, manured as on that occasion, and then laid down into permanent pasture. The seeds sown upon the Irish acre were 4 lb. of rape, 14 to 20 lb. of vetches, 2 bushels of perennial rye-grass, ½ bushel Italian rye-grass, 4 lb. of timothy, 4 lb. of cocksfoot, 4 lb. of alsike clover, and 4 lb. of white clover. In the part where clay and not bog or moss prevailed, 4 or 5 lb. of red clover were added; while for the purpose of learning the young sheep to eat roots, a very small quantity of turnip-seed was also thrown in.

Result.—The land thus treated was generally ready to carry sheep some time in August, and, without exception, the pasture laid down in this manner has excelled that sown in the course of an ordinary rotation. The rape and vetches afford useful feeding for sheep—no cattle are put upon the land—early in the first season; afterwards the vetches die out and leave a wonderfully close rich cover of grass and clover. The sheep take very kindly to this sort of food, and thrive remarkably well upon it.

Mr Young found it advantageous to sow, for variety of feeding, a small patch of mustard instead of rape. The mustard plant grows rapidly, affording good feeding six weeks after being sown. Sheep are fond of mustard, and it prevents liability to scouring.

In addition to the method of renewing the pasture land which Mr Young pursued, and which we have briefly described, being efficient for the desired object, it was also in itself a profitable

operation. The extra feeding which the rape, vetches, &c., afforded more than repaid the cost of the labour and manure which were employed in that work.

Improvements at Boon, Berwickshire.

Dr R. Shirra Gibb, tenant of the large farm of Boon, Lauder, in the county of Berwickshire, has done a great deal of successful work in reclaiming and renovating rough pasture-land. The ground reclaimed lies from 870 to 1070 feet above sea-level. The surface soil is variable, portions of it being strong clay, with gravelly knolls, and other parts thin, black-topped moorland, with peaty hollows. The subsoil consists of cold, retentive boulder clay.

Drainage, as a preliminary operation, was necessary on an extensive scale, and was carried out under a mutual agreement between the landlord and tenant.

The work of reclamation was begun in 1872 and continued till 1878 at the rate of about 80 acres, more or less each year.

After draining the land was ploughed, for the most part by horse labour, but occasionally Fowler's steam-plough was employed, and on one area of about 70 acres the work was done by the "Sutherland plough,"—a huge implement designed by Messrs Fowler & Co. for the Duke of Sutherland's famous reclamations at Lairg and Kildonan.

The dense, grassy, fibrous turf or heath turned over by the first ploughing was left to disintegrate and rot for from twelve to eighteen months, when it was cross-ploughed and harrowed. The land was then dressed with 5 tons of lime-shells per acre, and was sown with turnip-seed, broadcast or in drills, according to the fineness or roughness of the surface. From 3 to 5 cwt. of superphosphate per acre was also applied for this crop. The turnips were consumed on the ground by sheep, the treading of the stock doing much to aid in the further breaking up of remaining sods.

Only on one or two occasions was any oat crop grown, and even with the high prices then current it seemed doubtful, owing to strong growth and unfavourable climate, whether reasonable profits would be obtained from oats. Generally the sowing down of the newly

reclaimed land was done with ryegrass, cocksfoot, and clovers, without other crop, excepting rape, which was eaten off by sheep about three months after sowing.

When the agricultural depression began in 1879, the work of reclamation was discontinued, and was not again resumed. The reclaimed land got no further treatment for a good many years, and it deteriorated to such an extent as to become almost as worthless as it was prior to the first ploughing. Most of it, indeed, reverted to a very rough condition. Only a few sickly plants of clover were visible, almost the sole food for stock being moor-bent (*Agrostis*), which made up about 75 per cent of the herbage, sweet vernal and sedge providing the rest.

At this stage it was decided to attempt the renovation of the land, and from this work greater success has been attained than from the original reclamation. The process of renovation was, in the earlier stages, similar to that of the reclamation. When ploughed the land was now found to be full of the thick-matted fibrous roots of *Agrostis* and sedge, and when the furrows had lain a few months there came up a strong growth of fresh young grass, not only on the upturned soil but also between the furrows. The old grass on the unploughed land was so rough, coarse, and indigestible that stock would scarcely touch it, but sheep ate the succulent young growth with avidity, although this fresh growth also came from the roots of the moor-bent and sedge. The unsown pasture obtained in this way was found to be most useful, and its value was considered equal to the original rent of about 10s. per acre.

In the following year the ground was cross-ploughed, harrowed, and generally made into as good tilth as could be obtained, though half-rotted sods were still fairly plentiful. A dressing of 7 cwt. of basic slag and 20 cwt. of ground burnt-lime was applied per acre, and turnip-seed was sown thinly—about $1\frac{1}{4}$ lb. per acre. The seed was sown broadcast, and to ensure even distribution it was mixed with sawdust. The turnips, which were allowed to grow unthinned, were consumed on the ground by sheep. Here, again, the treading of the sheep did much to accelerate disintegration.

In the third year another crop of turnips was taken, but this time, the state of the tilth being finer, the seed was sown in drills, after the application of from 5 to 7 cwt. per acre of basic slag. Again the crop was consumed on the ground by sheep. The amount of winter food for sheep provided by these crops of turnips has always been large, it being considered that by the end of the third year the produce has been about sufficient to meet the annual rent and other outlays.

In the fourth year the land has been sown down with grass- and clover-seeds, without any other crop. The reason for the omission of a grain crop with the grass-seeds is that at such a high altitude the rank crop that would grow on this land, so full of freshly decayed organic matter, would not often ripen sufficiently early to admit of its being harvested in a profitable condition. The mixture of grass-seed usually sown consisted of 5 to 6 lb. of timothy, 7 lb. of meadow-fescue, 7 lb. each of perennial and Italian ryegrass, 2 lb. of rough-stalked meadow-grass, and 6 lb. of white clover and 3 lb. of alsike clover per acre.

Although a certain amount of deterioration takes place, probably to an increasing extent each year, it has not been thought advisable to re-plough any portion of the land thus renovated, the pasture in its seventh year remaining valuable beyond expectations. No doubt, in course of time the land will again have to be put through a renovating process.

Dr Gibb estimates that these methods of reclamation and restoration have generally left him a balance to the good, equivalent to about 10s. per acre for each of the ten years of the "rotation."

Dressings of basic slag and ground burnt-lime have almost invariably given good results on this land. White clover, which is rarely seen in the unreclaimed land here, comes up luxuriantly in the reclaimed and renovated land, and the slag and lime are believed to have something to do with this. The clover, of course, in itself adds greatly to the value of the pasture, and it likewise does good by tending to keep in check *Agrostis* grass, which is inclined to become unduly prevalent and strong upon this land.

IMPROVEMENT OF HILL PASTURE.

The improvement of hill pasture and of grazing land which cannot be advantageously put through a course of cropping is a matter of considerable difficulty. In all probability the prospects of return would not justify a heavy outlay, and without this it is not easy to effect any marked improvement in the pasture.

Deterioration of Hill Pastures.—It is not surprising that complaints of deterioration in hill pastures should occasionally be heard. By the system of grazing pursued on these, there is a gradual exhaustion of the natural resources of the soil without the slightest compensation from any external source. The repairing and replenishing forces of nature are ever at work, but these are usually inadequate to recoup the land for what has been removed from it in the bodies of the animals reared upon it. Deterioration becomes manifest in the pasture, and the farmer is puzzled to know what should be done.

Cropping.—On hill pasture little can be done with advantage in the way of improvement by tilling and cropping the land. In certain cases small portions have been renovated by this method, but the cost is great, and the results rarely satisfactory. The process of renewing the grasses on poor land followed by Mr Young of Brockley Park, Stradbally, Queen's County, Ireland, and just described, might be carried out with good results on low-lying permanent pasture which has become deteriorated.

Manuring Hill Pasture.—Many experiments have been tried in the way of manuring worn-out hill pasture with bones, superphosphate, and other manures. The effect on the pasture has usually been marked; but, as a rule, we believe it is acknowledged that the results are too uncertain to warrant such heavy expenditure, at anyrate on an extensive scale. A few patches of specially good pasture, on well-sheltered low-lying parts, are a great advantage on a pastoral farm, and these may profitably have an occasional dressing of artificial manure.

The manuring of hill pasture, however,

has never been regularly or extensively practised in this country.

Liming Hill Pasture.—In the improving of hill pasture, lime has been used much more extensively than other manures, and the results from lime have, as a rule, been highly satisfactory. It can hardly be expected that it would pay to spread lime upon poor black moory pasture. The attempts at improvement by lime as by other manures should be confined to the green land. If the land is wet it must first be drained, either by underground drains, or by open or "sheep" drains (the former are the more effective, though of course the more expensive), and about a year or so after the draining has been completed, the lime may be spread. It used to be considered that a good dressing would be about four to six tons of lime per acre; but the more general custom now is to give smaller dressings at shorter intervals.

Effects of Lime.—The lime has a wonderful effect upon the rough green pasture. It brings up a growth of sweeter, greener, and more juicy grasses than grew there before, so that in a few years the character of the herbage is vastly changed. The sheep soon discover the portion that has been limed, and show by their partiality for it what they think of the "lime-sweetened" pasture. Six months after the application of lime they feed on the land with avidity.

Enduring Effects of Lime.—Moreover, the good influence of lime upon pasture is by no means short-lived. It endures for twenty or thirty years, and has in many cases been visible for even a longer period.

Heather-burning.—By systematic and judicious heather-burning, much may be done to improve black hill pasture.

Bracken-cutting.—Brackens should be kept in subjection by cutting with the scythe or other instrument. If they are allowed free growth, they may seriously lessen the supply of pasture. On the other hand, a clump of rank brackens here and there may be an advantage on a hill-farm, on account of the excellent shelter afforded to lambs.

Irrigation.—Hill pasture may be greatly improved by irrigation. In many cases where streams or springs exist, this may be carried out with little trouble or

expense. Water from running streams is preferable to water immediately from the spring. By a network of shallow runs, the water may be carried over black or partially barren land, which will be thereby much improved for pastoral purposes. This work of irrigation is carried out in spring and early in summer.

A Mid-Lothian Example.

A good example of what might be done in the improvement of hill pasture by draining and liming without the aid of tillage was provided on the compact adjoining little estates of Baadpark and East Cairns, Mid-Calder, the property of Mr William Hamilton. These estates lie on the north side of the Pentland Hills, running from 900 to 1800 feet above sea-level. The geological formation is carboniferous sandstone. At a former period portions of the land had been under cultivation, but had been allowed to go back to natural pasture. At the time Mr Hamilton began his improvements even the once-cultivated land was producing coarse herbage of poor feeding quality, while the other portions were in their natural state, growing bent, other coarse grasses, rushes, heather, &c. Most of the lower-lying land was green on the surface, but the pasture was coarse and wiry.

Draining.—The improvements consisted of tile-draining and liming. The drains were cut from 6 to 16 yards apart, and from 3 to 5 feet deep, according to the nature and condition of the land. Two-and-a-half-inch tiles were used for the most part, and Mr Hamilton stated that if he had the work to go over again he would be inclined to use 3-inch tiles. The drains have worked admirably, but they, of course, require a little repair now and again.

Liming.—The lime was spread on the surface at the rate of about six tons of shells per acre. The liming of the wet land was delayed about a year after the draining, so as to allow the soil to get rid of its excess of water. Such portions of the green land as were naturally dry were limed without being drained, and on these and on the drained land the lime was equally beneficial.

Cost.—These improvements, which were begun in 1870, extended over an area of nearly 300 acres. The drain-

ing cost on an average about £5, 10s., and the liming about £4, 4s. per acre.

Results.—The total sum expended was about £1800, and it was considered that the investment was a good one. By the draining and liming the character of the pasture was entirely changed. A growth of fine nutritious grasses came up in place of the coarse wiry herbage which before covered the ground.

Improvements at Glenbuck.

In his report on "The Improvement of Hill Pasture," in the *Transactions of the Highland and Agricultural Society*,¹ the late Mr Alexander Macdonald gave the following notes in reference to improvements on hill pasture carried out by Mr Charles Howatson of Glenbuck: "The farm of Glenbuck, Lanarkshire, which carries one of the finest sheep stocks in Scotland, has been vastly improved through liming and draining by its enterprising owner and occupier, Mr Charles Howatson.

Draining.—"The greater part of it has been intersected with tile-drains, most of them 18 feet apart, and others 36 feet. Between each of those 36 feet apart, a shallow tile-drain is sunk, and is found to do good work. The size of the tiles used is 2½ inches, and the open drains, of which there are a great many, are 20 inches wide at the top, 18 inches deep, and 9 inches wide at the bottom. The cost of laying the tile-drains 18 feet apart and at the ordinary depth was about £9 per acre. Mr Howatson recommends in cutting open drains that all stones or tree roots which may impede the spade should be extracted, and the earth taken out removed 3 feet off the side of the drain.

Liming.—"Lime has been applied to the pastures at various times, costing as a rule 50s. per acre. By this system of top-dressing the character of the pasture has been materially enriched and improved, and parts of it which were limed some thirty years ago are still green and vigorous, while the adjoining land that got no lime is perfectly bleak and sterile.

Breaking up Unsuccessful.—"With a view to compare the results of an experiment in breaking up hill pasture, in

¹ Fourth Ser., xix. 170.

trying to improve it, with the liming and draining of it without breaking it up, Mr Howatson trenched $2\frac{1}{2}$ acres, gave it two tons of bone-manure, and sowed it down with grasses and clover, but it is not likely to prove successful. It cost nearly £17 per acre. Mr Howatson finds that ploughing, before top-dressing hill pasture, is no advantage whatever, while it incurs considerable expense."

Trials in Northumberland.

With the view of throwing light on the top-dressing of poor pastures, an interesting set of experiments was begun in 1897 at Cockle Park, Northumberland, under the auspices of the Education Committee of that county. A notable feature of these experiments was the plan of gauging the results by the increase in the fasted live weight of the sheep kept on the different plots. The value put on the increase in live weight was $3\frac{3}{4}$ d. per lb. In arriving at the final results, the increase in live

weight on the untreated plot was deducted from the increase on the other plots, and the value of this had deducted from it the average annual cost of the dressing.

The soil on the trial field is a poor clay and clay-loam, from 4 to 12 inches deep, lying on a subsoil of poor yellow boulder-clay. It was formerly under cultivation, and grew wheat till about 1850, but has for many years been lying in permanent pasture. In its best days in pasture it was not worth more rent than about 10s. per acre, and when these trials began the pasture was poor and benty, worth only about 2s. 6d. per acre.

Each plot was stocked with as many sheep as men of skill thought it capable of carrying, the grazing being in every way conducted in accordance with good management.

Each plot extended to three acres. The manuring of the different plots, and the results for the nine years, 1897-1905, are shown in the following table:—

Plot.	Treatment and its total cost for nine years, 1897-1905.		Average of nine years, 1897-1905.		
	Treatment.	Cost.	Live weight increase per sheep over plot 6.		Annual gain or loss (—).
			Amount.	Value at $3\frac{3}{4}$ d. a lb.	
		s. d.	lb.	s. d.	s. d.
1	Dec. cotton-cake fed on plot, total of 597 lb. 1897-8, again 1903, and again 1904 ¹	116/-	69½	21/9	8/11
2	Common lime, 4 tons 1897, and again 1903.	100/-	12½	3/11	7/3
3	Basic slag, 10 cwt. 1897	23/6	79½	24/11	22/3
4	Basic slag, 5 cwt. 1897, and again 1900	23/6	66	20/8	18/-
5	Superphosphate, 28%, 7 cwt. (100 lb. phos. acid) 1897, and again 1900	36/-	57	17/9	13/9
6	Untreated throughout	—	—	—	—
7	Supers. as on plot 5; and sulph. potash, 100 lb. 1897, again 1899, and again 1903	62/-	65½	20/7	13/8
8	Supers. as on plot 5; and ground lime, 10 cwt. 1897, again 1899, and again 1903	70/-	79½	24/9	17/-
9	Supers. as on plot 5; and sulph. am., 84 lb. (17 lb. N.) 1897, again 1899, again 1900, and again 1903	75/-	54	16/11	8/7
10	Diss. bones, 6 cwt. (100 lb. phos. ac. and 17 lb. N.) 1897, and again 1900 ²	66/-	61½	19/3	11/11

¹ Each lot of cake contained 42 lb. nitrogen and (assumed) 18 lb. phos. acid and 9 lb. potash

² Plot 10 received half the total amount of nitrogen applied to plot 9.

5 cwt. slag contain 100 lb. phosphoric acid. 100 lb. sulphate of potash contain 50 lb. potash. Dissolved bones, 1906, contain 100 lb. phosphoric acid and 22.8 lb. nitrogen. 142 lb. nitrate of soda contain 22.8 lb. nitrogen.

The cost of manures per ton was as follows: Basic slag, £2, 7s.; superphosphate, £2, 12s.; sulphate of potash, £9, 14s.; sulphate of ammonia, £13; dissolved bones, £5, 10s. Decorticated cotton-cake cost £7, 5s.; common lime, 12s. 6d.; and ground lime £1 per ton.

The results, it is seen, were highly favourable on several of the plots, most notably on the plots treated with basic slag.

The plots were stocked with sheep in summer only, and a good deal of rough foggage which remained was eaten by cattle.

Trials in Scotland.

The favourable results obtained in the trials at Cockle Park led to a set of trials, on similar lines, being conducted in Scotland, the Scottish trials being carried out jointly by the Board of Agriculture, the Highland and Agricultural Society, and the West of Scotland Agricultural College. The centres of the trials in Scotland were—Sunderland Hall in Selkirkshire, Boon in Lauderdale, Naemoor in South Perthshire, Hillridge in Lanarkshire, Holystone in Dumfriesshire, Boreland in Kirkcudbright, and Auchnaskeoch in Argyllshire.

In most cases the trial ground in Scotland is higher lying and colder than at Cockle Park, and the grazing of less annual value. On this account there was no expectation that such favourable results would be obtained.

The treatment of the plots, the stocking, the gauging of the results, and the general management of the trials, were on the lines pursued at Cockle Park. The Scottish trials began in the year 1901, and were continued on the original lines till 1907, when a report on the results was prepared. The general conclusions to be drawn from this report are as follows:—

1. That the great and rapid improvement which was effected by manures, and especially by basic slag, on the plots at Cockle Park, was not obtained on any of the plots in Scotland.

2. That an improvement was effected by all the manures, but that basic slag is the only manure which has effected sufficient improvement to make the results remunerative.

3. Even in the case of basic slag, on the average several years elapsed before sufficient return was given to pay for the slag.

4. Potash manure applied along with basic slag, though it gave a small increase in most of the experiments, especially in the first two years after its application, did not give sufficient return to repay its cost.

5. Superphosphate and lime, though in all cases giving a considerable return in increase of mutton, did not give sufficient to make the dressing remunerative. It never gave so great a return as the cheaper dressing of slag alone.

6. The feeding of cake on the plots gave the smallest return of all for the expenditure.

7. On some of the experiments in Scotland the soil was covered with a very thick coarse sod of grass of poor quality, chiefly *Agrostis*. On such land clover plants have not enough room to develop, and in these experiments the effect of the manure was shown only very slowly. In some cases sheep alone were unable to eat down the grass sufficiently, and better results were shown when both sheep and cattle were grazed on the plots.

The general results of the Scottish experiments went to show that on poor and high-lying land in Scotland the remarkable results which were obtained at Cockle Park are not likely to be realised. As a rule, the only manure which can be expected to give a remunerative result is a cheap dressing of basic slag.

CLAYING LANDS.

At one time or other a good deal has been done in different parts of this country in the way of claying land. Where the practice has been carried out with good judgment it has usually been followed with good results.

Benefits of Claying.—Where the surface-soil consists chiefly of shifting sand or of soft mossy matter, its agricultural value may be improved by spreading and mixing with it a layer of clay, chalk, or marl. This admixture binds

the sandy material and increases its cropping capabilities. The clay or marl is usually dug from the layer below the soil with which it is to be mixed. The cost of carting the clay from any considerable distance would be so great as to render the operation unprofitable. Chalk, however, is often conveyed long distances for the purpose of being mixed with soil.

Professor Wrightson says that thirty or forty yards of clay per acre has a wonderful effect in binding sands together; and mentions that in some counties, as in Norfolk, marling is thoroughly appreciated. Marl or clay pits are opened in the fields, and from forty to sixty cart-loads are applied per acre. The lower chalk is the best material for chalking. Large quantities of chalk are carried upon the Thames in barges for application to the heavy soils of the London clay, and to the heavy marine clays which extend still nearer to the Essex coast.¹

Clay Pits.—This process of claying the soil, which may conveniently fill in work for several days in winter, is in some cases conducted in this manner: Within the four sides of the field to be

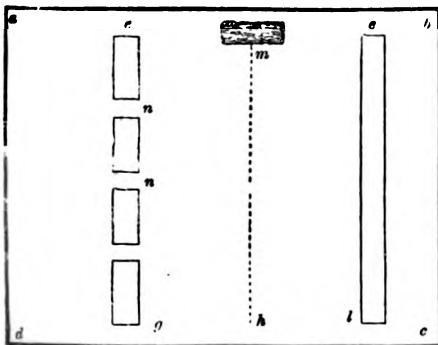


Fig. 282.—Claying of soil.

- a b c d Four sides of a field.
- e f Lines of pits out of which the clay is taken.
- g to h Distance, 12 yards.
- m Where the first surface-soil is laid down.
- n n Spaces of ground left untouched between the pits.
- m h Half-way between the lines of pits.

clayed, fig. 282, two lines of pits are set out, the clay of which is to be taken. The space between the pits depends on the depth the clay lies on the surface.

If the clay is deep, the distance between the pits is 12 yards; if shallow, it is extended to 20 yards, and varying between these two extremes. When the distance has been determined on, it is marked by a plough making a furrow in each line of pits. The width of the pits depends also on the depth of the clay: if it is 2 feet deep to the clay, the width is 3 feet 3 inches, but if 6 feet and upwards, the width is 4 feet.

A pit is dug in the first line, which should be begun near the upper fence. At half-way between the lines of pits, the surface-soil taken out of the first pit is laid down. The pits are made 9 feet in length. Should the clay be far down, the sides of the pit should be supported by planks, or framework of wood, to prevent the earth falling in, and to protect the lives of the men working in them. Lives have been lost through neglect of this precaution.

Spreading the Clay.—The clay as it is dug out is taken up with a fork or spade by a man or boy, and thrown equally over the space on both sides of the pit in which the men are working. Two good spits of the spade generally afford the requisite quantity of clay. After one pit has been sufficiently dug out, another is formed along the line, spaces of the ground being left untouched between the pits, of sufficient strength to support the sides from curving in.

The upper soil of the second pit is put into the first pit, to fill it up as far as it will go, and the clay is taken out of the second pit and spread upon the surface, in the same manner as that out of the first pit; and so on, from pit to pit, until all the pits in the line are dug.

When the first pit in the second line is begun, its surface-soil is wheeled to fill up the last pit of the first line; and when all the pits have been dug out in the second line, the surface-soil taken out of the first pit of the first line is wheeled to fill up the last pit of the second line.

In this manner, with every two rows of pits is the entire field spread over with the clay. The pits are levelled up afterwards with the adjoining soil by the plough. A little frost does the clay good by pulverising it, and makes it more ready to mix with the soil; but it is better to plough the clay in soon than allow it to

¹ *Prin. of Agric. Praes.*, 113.

become too hard either by drought or frost.

If the clay had to be carted upon it thus, the claying of land would be attended with much trouble and expense.

To cover an acre of soil with only one inch deep would require 180 cubic yards of clay.

Is Claying injurious to Sheep?—Mr Henry Woods, in his essay on sheep, asks, "Does clayed land materially affect the health of the ewe? I know the prevalent opinion is that it does, and probably it may; but I say that it is also very much within the control of the flock-master himself. I believe that with the care and intelligence which a person may bring to bear upon the matter, it may be very much controlled; and I will give you some practical experience on this point. I have been told, time after time, that the Waterloo Farm would kill any sheep—no matter whether they were hoggets or ewes, or any other sort of sheep, they could not live upon it; and still more unhealthy would it be if it was clayed. And as to ewes, the man would be mad who would attempt to keep them. Now that farm has been clayed very heavily; it has been clayed, marled, and chalked. All those three materials, which are held to be injurious, have been applied; and what has been the result?" The results were that the health of the sheep stock was excellent, with a death rate of under 5 per cent per annum, including lambs.¹

Mixing Soils.—The opposite process to that described above may also, in certain cases, be carried out with advantage. That is, where the surface-soil consists chiefly of stiff adhesive clay, its texture and usefulness may be increased by the admixture of a quantity of sand.

Professor Wrightson says: "The mixing and moving of soils may sometimes be carried out with benefit. Wherever clay or sandy soils exist in close proximity, an interchange may be effected with good results, although the effect of clay upon sandy soils will always be more apparent than the reverse operation of adding sand to clay.

Top-dressing bare Heights.—"The carting of soil on to bare brows is a work

that may profitably occupy horses during winter. The tendency for soils to slip down hillsides, and gradually accumulate at the bottom of slopes, is well known. Every tillage operation tends to effect this result, and in process of time the upper portion of hill becomes denuded of soil, while there may be an excess of soil at the bottom. The restoration of this soil to the upper portion of the field is a beneficial act."²

CHALKING LAND.

A top-dressing of *chalk* is given in several districts of England for affording calcareous matter to the soil. It has a striking effect upon fresh-broken-up land; but at length it loses its efficacy. It is applied again when its effect becomes inert.

For this purpose the solid chalk of the lower stratum is preferred to the more porous substance near the surface. It is taken out of pits in lumps, which are put upon the ground to be dressed; and, the lumps being wet, the frost in winter causes them to fall down into a powder, which is then spread over the surface of the ground. Dry chalk will not fall down, and is therefore useless for the purpose.

Chalk is used in Hampshire to render the soil more loose, and in the wolds of Yorkshire more firm.

The quantities applied vary. In Essex, in the clay-land district, about fifteen cart-loads, of 40 bushels each, are considered a full dressing on one acre. In Lincolnshire, 80 cubic yards of chalk are applied to one acre.

MARLING LAND

The process of *marling* is similar to that of claying. Marl is a clay containing particles of chalk, which are visible in the mass of clay. The marl is applied both to heavy and light land. On heavy land it is used on newly-broken-up pasture, and mixed with farmyard manure in compost. On light soils it is more extensively employed, and its benefits

¹ Wood's *Breed. and Manag. Sheep*, 21-30.

² *Prin. of Agric. Prac.*, 113.

are chiefly derived from an improved texture of the soil.

From 40 to 50 cubic yards are applied on an acre. Its action produces better quality of grain and regularity of crop. Excess of organic matter in a new soil loosens it, which the marling corrects; dry and loose texture of sand is rendered more adhesive and retentive of moisture; and peat is benefited by consolidation and the supply of inorganic matter.

The following analysis gives a fair idea of the composition of a clay marl. The specimen was found in Ayrshire:—

Carbonate of lime . . .	8.4
Oxide of iron and alumina . . .	2.2
Organic matter . . .	2.8
Clay and silicious matter . . .	84.9
Water . . .	1.4
	99.7

The composition of *peat shell-marl* of Logie, in Forfarshire,—a county which afforded and used so large a quantity of this substance as positively to become detrimental to the soil,—is this:—

	From the top of the bed.	From the bottom of the bed.
Carbonate of lime . . .	77.6	81.7
Oxide of iron and alumina . . .	1.8	0.6
Organic matter . . .	14.6	14.6
Insoluble, chiefly silicious matter	6.0	3.1
	100.0	100.0

Shell-marl retards the ripening of corn crops, while lime hastens their maturity. It is not suited to gravelly soil, and its tenacity in rendering and keeping all soils loose for a long time is remarkable.

PARING AND BURNING.

The practice of paring and burning was at one time pursued to a considerable extent, but has very properly become almost a thing of the past. For the sake of those not acquainted with the process, we may here briefly state the arguments for and against the practice.

Paring is the removal of a thin portion of the surface of the ground, with what may be growing upon it. *Burning* is the reduction by fire to a state of powder, of what has been pared off.

Object of Paring and Burning.—The object of the process is to assist in reducing rough surface-soil into a workable condition more speedily than could be accomplished by the slower influences of tillage and cropping.

Advantages of Paring and Burning.—The advantages which result from the operation are—

(1) The change produced in the mechanical condition of the soil, the texture being altered—opened up—especially upon stiff clays, by the admixture of the ashes which result from burning.

(2) In peaty soils, or where a large amount of rank and coarse vegetation covers the ground, a complete change is

quickly effected by the process—rendering the future breaking-up of these soils by the plough a matter of easy accomplishment.

(3) Leas and old pasture are frequently infested so much by the larvæ of insects, notably wire-worm (*Elater lineatus*) and the grub of the daddy-longlegs (*Tipula oleracea*), that the prospect of the corn crop is rendered doubtful. These, as well as the seeds of noxious weeds, &c., are destroyed by this practice.

(4) Burning is one of the quickest agents employed in agriculture for the conversion of the dormant ingredients of the soil into an active or soluble form. Heat breaks up the various compounds, separating the acids from the alkaline bases, which, forming more simple compounds, are to a greater extent soluble in water, and in consequence in a fit state to be assimilated by the roots of plants.

Disadvantages of Paring and Burning.—These advantages are obtained at the sacrifice of all the organic portion of the soil, which, being volatile, is dissipated by combustion, passing into the air in the form of gaseous bodies. It is also found that while

potash is rendered more soluble by the action of heat, phosphoric acid is rendered nearly insoluble. Over-burning also frequently occurs, and this on a clay soil will convert the residue into brick-dust, a spreading of which may increase the friability of a soil, but can have no action in increasing its fertility, as it becomes insoluble matter. Then, in peaty soils, in dry weather, the former may ruin its producing power by the total destruction of the humus or vegetable matter.

Useful on Certain Soils.—From the foregoing it would be inferred that paring and burning might be carried out with advantage on stiff clays, where the loss of the small amount of organic matter which may be present is compensated by the increase of soluble inorganic matter; or on a soil which is made up largely of inert vegetable matter, such as peat; and on soils infested with larvae, or seeds of weeds. Some calcareous soils might perhaps also be burned to advantage.

Lime Essential.—But no matter what soil is burned, the full benefit of the operation cannot be obtained unless lime is present. Lime is absolutely necessary for the liberation of potash and soda. It is good practice, therefore, to give a coating of lime where such is deficient before the work of paring and burning is commenced; while after completion the soil ought to be heavily manured with nitrogenous manure.

Paring and Burning Condemned.—Still, with due recognition of all that has been claimed for the practice, we are bound to say that we regard it as entirely out of keeping with the spirit of the age. This view of the matter is well expressed by the late Mr George Brown, Watten Mains, Caithness, who, writing for this edition, says: "The practice is objectionable, and is based upon wrong principles. All the advantages claimed for it may be derived by following the ordinary routine of farm practice. If a farmer has rough land let him plough it early in spring, summer, or autumn—the earlier the better—and leave it to the ordinary forces of nature until the following spring; sow it then with oats, and again plough early, taking another crop of oats. In

the third year it will be ready for a turnip crop. If a little rough after sowing, give a turn of a heavy roller along the drills, and a heavy crop will be the result. This method (which is in accord-

ance with sound practice, backed by the latest researches of science), the writer has seen pursued with success upon hundreds of acres of waste land and heath when first reclaimed."

Methods of Paring and Burning.—Having thus presented the prevailing views for and against paring and burning, we now append some notes as to the different methods of carrying out the process.



Fig. 283.
Common
spade.

Various implements are employed to execute paring and burning. The common No. 5 garden spade, fig. 283, with a sharp edge and its corners a little worn by work, removes rough herbage very well, and the turfs can be set up at the time by the workmen to be dried. But the labour with it entirely is expensive, and is seldom incurred.

Flaughter-spade.—A more expeditious implement is a spade of a different



Fig. 284. - Flaughter-spade at work.

form, fig. 284; the face of which is angular and sharp, the blade 9 inches broad and 15 inches long; the straight side of which is turned up square 3 inches, with a cutting-edge in front; the helve is 5 feet long and flat, provided with a broad cross-handle 2 feet long,

fastened at right angles to the helve. The blade is set at an angle to permit the handle to be elevated to a man's haunches, while the blade works flat upon the ground. It is called in Scotland the *flaughter-spade*, from the Teutonic verb to *flauch* or take off the skin.

The mode of using this implement is this: "The workman is provided with a short leather apron faced with two boards in front of the groin, the apron being buckled round the waist and round the upper part of the thighs. The blade of the instrument is laid flat on its sole, and its point is made to enter the ground by a push of the body of the workman upon the handle placed against the boards in front of his groin, and there held by both hands. The body gives successive pushes, longer or shorter, as the nature of the ground admits; and the point is made to dip deeper, keep level, or move upwards, by the direction of the hands, according to the thickness of the surface to be removed. At each push the point cuts forward under the turf, while the cutting edge severs the loosened turf from the solid surface. When the turf is 1 or 2 feet in length, according to the state of the surface, it is turned upon its back or side, on the pared surface on the left hand, by a sudden jerk of the handle. The edge of the spade is kept sharp with a scythe-stone. The thickness of the turf removed depends on the strength and skill of the workman, but it seldom exceeds 2 inches even in the softest parts of the ground, and more often $1\frac{1}{2}$ inch. It takes a man one week to turn over one acre of ground, and he is paid 3s. or 4s. a-day, or 20s. an acre, for his hard work."

Paring-plough.—A more expeditious method still is to pare off the surface with a horse and plough. An English paring-plough, made by Vipan & Headly, Leicester, is represented in fig. 285. This plough is specially adapted for paring the tough surface off an old pasture about to be broken up, or for paring stubbles to facilitate the removal of surface weeds. It pares to a depth of from 1 to 3 inches, and with a pair of horses will cover from $1\frac{1}{4}$ to 2 acres per day.

The ordinary plough may be fitted for paring by having the feather of its share widened to from 12 to 15 inches. Fig.

286 is the share of the common plough, the breadth of whose feather is 10 inches, but by welding a wing 3 inches in breadth, having a sharp edge upon the outer side of the feather, the paring-face is increased to 15 inches in breadth from the land-side of the share. When the paring is finished, the wing can be cut off, and the share is again fit for ordinary use. The mould-board cannot

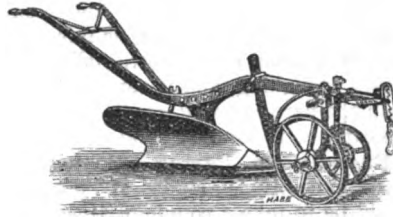


Fig. 285.—Paring-plough.

lay over so broad a furrow-slice as 15 inches as it lays over in lea; the broad furrow-slice being partly rolled over upon itself, which is in its favour for drying.

Paring with the plough is, of course, much less expensive, as well as more expeditious, than paring with the *flaughter-spade*. Where the ground is even, the plough with wide share will turn over the entire surface; but in uneven and much-broken ground, where stones abound, it

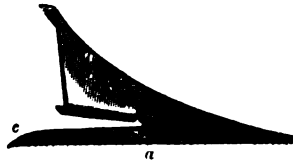


Fig. 286.—Paring-share.

a Breadth of sock, 10 inches.

c Ear of feather, 15 inches in breadth from land-side.

cannot be used, and the *flaughter-spade* must be employed; while the common spade is used in small deep hollows, or among thick masses of herbage. Thus all the implements may co-operate to complete what one alone could not do so well.

When the turfs are laid over by the spade, the workman might set them up one against the other, though not so neatly as by hand. The *flaughter-spade*, taking up a long thin turf, cannot get

quit of it without either laying it flat or setting it partly on edge. The broad continued turf laid over by the share of the plough must fall flat upon the ground, and be set up by hand to be dried. A *paring-plough*, which has been used in parts of England in the fens, pares the turf by means of two angular shares with the wings facing each other, and just crossing the centre line, one being a little before the other; and they are attached to shanks, placed in front of the mould-board, upon which the turf is raised in a manner similar to the furrow-slice in ordinary ploughing, and is set on its edge upon the pared ground, ready to be dried, as neatly as if done by hand.

Expeditious Paring.—Perhaps the most expeditious mode of procedure would be to take a couple of tines out of a common grubber and cross the land to be pared, then start an American chilled plough at the required depth. The breadth of the share and curve of the mould-board are suitable for the work, and by the previous crossing with the grubber tines, the surface would be left in good sized turfs for burning.

Time for the Process.—Paring may be executed any time during the winter and spring, but it is best and most easily done from February to April. It is difficult to do when the ground is dry and hard, but in boggy land it is best done in dry weather. While boggy land is very wet it cannot be done at all, the footing then being insecure, and the soil soaking with water; nor in clay land, when wet, as the surface soon becomes poached.

Drying the Sod.—The sods are set up on edge against one another in the way best to expose the largest surface to the air, to be dried in the quickest time for being burned. The long continuous turfs turned over by the ploughs require to be cut in convenient lengths with the spade before they can be set up to dry. In dry weather they are ready to be burned in about two weeks.

Process of Burning.—In burning, the fires must be begun with some combustible materials—as wood, chips, shavings; and at first they must be strictly attended to, in order to have the *first* turfs completely dried. After these have begun to burn, surround them with fresh sods to keep the fire in a smouldering

state, and not to flame or burn fiercely. A number of fires should be lighted one after the other, the field-workers carrying the turfs to supply them with fresh sods, placing them thickest on the windward side to keep down the force of the fire. This being the object, the turf, after the first dried ones, should not be too dry before the burning begins. The heaps are supplied with turfs until they attain a large size, capable of containing from ten to fifteen cart-loads of ashes, and the larger the heap the less effect has the air on the ashes.

The dried and burning turfs from one heap will supply fire to begin the burning of other heaps. To prevent the fire breaking into combustion through the night, the heaps should be well covered with fresh sods in the evening, partly to be removed in the morning. When the fire gets dull, a hole in the windy side, punched into the heap with a stake, will give it life. In a large heap there is no fear of the fire being extinguished, although there be no symptoms of activity on the outside. A heavy rain cannot put out the fire of a large heap.

To obtain good results, the burning should not be conducted in a thoughtless manner, but done to a plan previously fixed upon.

A Good Plan.—A good plan is to burn one row of heaps, then another, and to begin at that side of the field most convenient to plough the ground. Having gathered the turfs on both sides of a line of heaps, a space of ground will be cleared of turf; and as one line of heaps is constructed and burning, let another be begun from the end where the former line finished, until all the field has been heaped and burning. The charred turfs of the previous line will be easily carried across the ground to the line to be formed.

Cooling the Heaps.—The time that may elapse before the burned heaps become cold depends on the state of the weather, but it will be considerable if the heaps are allowed to cool of themselves. The hot ashes may be spread to cool, if required soon; but should wind arise after a heap has been broken, the ashes will be scattered, or be blown off the ground altogether. Caution is requisite in opening up a heap.

The Ashes.—When thick turf has been laid over by the plough, it will afford more ashes than the ground requires at one time. To avoid a superabundance of ashes, some pare as much turf in strips as will just supply the ashes wanted. To effect the stripping, the ear of the feather of the share is turned up with a cutting-edge. But where the herbage is rough, the strips left are as difficult to reduce as ever.

The better plan is, to pare and burn all the surface, and carry off the extra ashes to another field about to bear a green crop; and as carrying away ashes implies robbery of the land which has supplied them, a substitute should be provided in farmyard or other manure.

The burning of heaps in line clears the ground for the plough, which is feered between the heaps, to ridge the land in any form desired; and before the land is ploughed the ashes are spread upon it. This is the simplest mode of applying the ashes; for if they are not spread until after the dung for turnips has been laid on, as some writers recommend, the ashes will have to be carried off the field and then brought back when wanted.

Time to Plough in Ashes.—In some cases the ashes were spread and ploughed in immediately after the burning; in other cases the ploughing in was deferred for a time, probably for several months. This latter was considered to be the better plan. The superiority of the results from this method was believed to be due to the ashes having in their exposure absorbed ammonia from the atmosphere.

Changes involved in Burning Soil.

—The chemical and physical changes which occur in the burning of soil may be stated thus: Combustion and decay are synonymous;—the ultimate results from each are similar, but the proximate organic compounds are different. Combustion acts quickly, and dissipates organic matter in the form of carbonic acid, ammonia, and watery vapour. Decay acts more slowly, and allows these volatile substances to recombine with the alkalies and acids present in the soil, thus forming soluble salts, such as carbonate of lime, and nitrate of potash, or lime. Chief of the inorganic compounds is silicate of ammonia, which cannot be held as plant-food; but, according to Professor Tanner, in combination with this compound there are others—viz, silicate of potash and lime in certain proportions—forming double silicates. This compound is broken up by the action of heat, and the silicic acid having a greater affinity for ammonia, the potash is driven out and recombines with other free acids present. Lime, being rendered caustic by the process also, comes into contact with salts of potash, and liberates the base and combines with the acid.

Thus we learn that a constant change is taking place, the complex or insoluble compound being rendered simple or soluble, all being regulated by chemical affinity.

Apart from chemical action, burned clay, charcoal, &c., have a great power of absorption, and many maintain that the ammonia lost by burning is fully compensated by the power the burned residual matter has for absorbing this wonderful agent in plant-growth.

IRRIGATION.

The artificial watering of land is an ancient practice. Applied to certain soils and for certain crops it is usually highly beneficial in periods of drought. Indeed, wherever the rainfall is insufficient for a full production of crops, irrigation may be practised with good effect. Even in the humid climate of the British Isles,

where the total rainfall may be considered more than sufficient, the fall is often so irregular that artificial watering at times can be usefully resorted to, as it enables the farmer to apply moisture just in the required quantity, and when and where it is most needed.

Vast tracts of land in Egypt, India,

Australia, Canada, the United States, and elsewhere, are now growing wheat only by this means of assisting Nature. It is not generally recognised to what an enormous extent the wheat-producing area of the world has been in this way increased. In the above-named countries there are nearly 100,000,000 acres already under irrigation, and schemes have been projected, and are partly in progress, for bringing about 75,000,000 acres more under irrigation. This cannot be without effect on the corn-markets of the world. Irrigation, in fact, has been one of the chief factors in producing the cheap over-sea corn with which our home farmers find it so hard to compete. And, as farming is no longer the parochial business it was not so many years ago, it becomes more and more necessary for every class of farmer to note well what their competitors are doing.

In connection with the extent to which irrigation has stimulated wheat-growing in some of these countries, however, it is startling to be told, on the good authority of *The Miller*, that, both in Canada and the United States, where irrigation has been freely resorted to in wheat-growing, the grain has more or less deteriorated and lost some of the special characteristics for which the hard wheats from these countries had become favourably known. The wheat has softened, and the concentrated gluten property has been lessened. This discovery may put a check on the indiscriminate extension of irrigation grain-growing in these countries: at all events, it will call for a more careful study of the constituents of the grain grown by artificial watering.

Moisture and Vegetation.—It very often happens that the vegetable produce of soils is regulated more by the supply of moisture than by the store of other plant-food. The sterility of the desert is due to the deficiency of water rather than to the want of soil-food for the plant. Soils, indeed, will not produce vegetation of any kind unless they contain a considerable amount of moisture. Professor Church states that soils which contain no more than 5 to 9 per cent of moisture will yield none of it to the plant. It is well known that under skilful irrigation, or in a moist season, soils which are naturally poor yield wonderfully abundant

crops. On the other hand, no amount of manure or inherent fertility in the soil will produce even a moderate crop if the supply of moisture is insufficient.

Reasons for Irrigation.—It is not difficult to understand why moisture is of so much importance to the growth of vegetation. Growing plants usually contain water to the extent of from about 70 to 95 per cent, and the whole of this water has to be absorbed through the soil; for while plants give off a great deal of moisture through their leaves, they cannot absorb any directly from the atmosphere. It was found at Rothamsted that an acre of wheat in five months and eighteen days evaporated through its leaves no less than 335½ tons of water. And as has been remarked by Professor John Scott, every drop of this water was more or less instrumental in transporting an atom of food from the soil to some part of the plant. Plants indeed can take up their food only in a fluid condition, so that in the economy of plant-life moisture performs a twofold function of the greatest importance.

Professor Church states the reasons for irrigation as follows:—

“1. To make up for the absence of irregular seasonal distribution of rain, or for a local deficiency of rainfall.

“2. Sometimes a particular crop is irrigated because the plant is of an aquatic or semi-aquatic nature.

“3. To encourage early and rapid growth, by warmth of the water, or by the dissolved plant-food which it contains.

“4. That the land may be enriched and its level raised by means of the deposit from the water.”¹

Discussing the subject more fully, Professor Church remarks that the third of these reasons “is the determining cause of nearly all the artificial watering of land in temperate climates. It is not performed because the soil is dry and hot, for it is carried out mainly in the wettest and coldest months of the year. It is not performed because the crop to be raised is of an essentially aquatic nature, for ordinary grasses and meadow herbage are principally watered. But it is performed that growth may be stimulated

¹ *Ency. Brit.*, 9th ed., art. Irrigation.

and fed through certain agencies which the water brings to bear upon the vegetation in question."

Effects on the Soil.—Irrigation facilitates the decomposition of soluble organic and inorganic matter in the soil, and thus prepares food for absorption by the plant. Its immediate effect is to soften the soil, but ultimately land which is submitted to constant irrigation for a long period of time is liable to become injuriously dense and hard. Irrigation may sensibly affect the fertility of a soil by carrying into it atmospheric air and other gases, and organic and inorganic matter held in suspension or solution in the water used for irrigation. In the great majority of cases the influence of this is beneficial, but occasionally substances decidedly injurious to vegetation are introduced. By irrigation plant-food is carried towards the roots of plants, while injurious as well as useful elements are often conveyed beyond the reach of the plants, most probably into the drains.

Irrigation and Soil Temperature.—Irrigation has a direct and immediate influence on the temperature of the soil. In the winter season it will most likely communicate heat to the soil and protect it to some effect from the frost. In warmer weather, by promoting evaporation from the surface, it tends to cool the soil, thus moderating the influence of the extremes of cold and heat.

Irrigation and Drainage.—It is absolutely necessary that land which is to be irrigated shall be thoroughly drained. Even on some arid lands, or in climates where crops can be grown only by the aid of a plentiful supply of irrigation water, drainage is as essential as where the ground is naturally wet; because irrigation becomes a positive injury if the water is allowed to stagnate. For healthy and vigorous plant-growth, the moist soil must be filled with constantly renewed atmospheric air.

The beneficent effects of canal irrigation in the North-West Provinces of India have been much marred by the omission of a collateral scheme of systematic drainage in the original design of these works. By this oversight vast areas of country have been made swampy in the wet seasons; and the injury caused by the want of drainage has been

painfully brought home to the people, not only by the crops failing to derive the benefits which they otherwise would have done from irrigation, but by the prevalence of malarial fevers which were entirely unknown in some districts before the advent of these irrigation canals.

On the alkali lands of New Mexico, Utah, and Colorado, as shown by Professor Milton Whitney's valuable investigations on agricultural soils, reported to the U.S.A. Department of Agriculture, the present accumulation of alkali, which has frequently nearly reached the tolerance of plants, is entirely attributable to lack of good drainage. The evaporation in these semi-arid regions is unusually great, and with insufficient rainfall and injudicious irrigation, tends to an accumulation of alkali near the surface. With good drainage, and proper application of irrigation water, these salts are in a measure washed out of the soil, and the soil moisture maintained at nearly the same concentration as the water-supply.

Water-meadow Irrigation.—In the southern counties of England great advantage is derived from the water-meadows which are a feature in the farming there. The irrigation forces up an early growth which is a great boon to the ewes and lambs. Then follows a crop of hay, and after that again a heavy cutting of aftermath. It is within the mark to say that on many of these meadows the produce is doubled by the artificial watering. But even in the comparatively genial climate of the south of England, the success of these water-meadows depends entirely on the judicious management of the waterings, on the times of watering, and the periods for which the water is kept on.

Water-meadows for Highland Districts.—Great benefits may also at times be derived from water-meadows in some of our Highland districts where hay is the most valuable food for stock in winter that can be raised at such altitudes; but the northern climate is so different, in rainfall, temperature, and variableness, that the good effects of artificial watering cannot be relied on to the same extent as in the south. That the formation of water-meadows is practicable in all our Highland glens is

apparent from these statements of G. Stephens, which we commend to the consideration of such as may betake themselves to hill-farming:—

“Fallaws Meadow, on Sir George Montgomery’s large sheep-farm, containing 15 acres, was enclosed from moorland, in 1816, and, by collecting the water from the surrounding sheep-drains, 5 acres are partially irrigated, and the remaining 10 are top-dressed with the manure made from part of the produce which is consumed in winter by the sheep of the farm in a wooden shed near the meadow. By this simple method of improvement, 15 acres of common sheep pasture-land gave the proprietor from 3500 to 4000 stones of hay per annum, averaging 6d. per stone. In that year of drought, 1826, the hay of this meadow was sold from 1s. to 1s. 3d. per stone.

“What an immense advantage to a sheep-farmer! By this simple process of enclosing and cutting a few small feeders and drains, the owner is enabled to provide food for his flock, when his less fortunate neighbours’ sheep must either starve or be supplied from the farmyard; but I am afraid there are few sheep-farmers who are so fortunate as to have any hay over and above what is requisite for stock at home. Sir George fed the same number of sheep on the farm as he did before the meadow was cut off and enclosed, and I am fully persuaded that the same improvement might be made on almost every sheep-farm in Tweeddale; for in almost all of them there are situations where 5, 10, or 15 acres might be enclosed and partially irrigated, as in every pastoral district there are numerous rills which might be easily collected, and used to the greatest advantage, at a very trifling expense; so that, instead of being obliged, in snowstorms, to send 50,000 sheep to a milder climate of the south parts of Dumfriesshire, where the owners are obliged to be at the mercy of their neighbours,—not to mention the very serious injury the flocks receive by so long and fatiguing a journey,—by adopting the above system of improvement a considerable portion of the losses generally sustained would be prevented.”¹

Time for Irrigation.—“As it is im-

practicable to irrigate meadows in winter in Highland districts, that process should be delayed till every chance of frost has subsided—until May, after which there will still be sufficient time for a crop of natural hay to grow, be cut down, and won, before the departure of summer. Such a meadow is useful in a backward spring for the support of ewes and lambs: and the sheep belonging to Sir George Montgomery would have inevitably perished in the cold and backward spring of 1826 had it not been for the grass afforded by a water-meadow from the middle of April to the beginning of May; after which latter period the meadow was irrigated, and produced nearly 300 stones per acre. The attention of hill-farmers cannot, therefore, be too strongly drawn to the subject of water-meadows. Any attempt to irrigate meadows in such situations in winter, and to pasture them in early spring, would but injure the meadow by means of frost, and at the same time rot the sheep; but sheep may be pastured, if necessary, in perfect safety on dry meadow-land in spring; and the meadow, on being afterwards irrigated, might yield a good crop of hay.”²

Soils for Irrigation.—Irrigation will, as a rule, give the best results on sandy and gravelly soils. A retentive soil may be injured by irrigation, for instead of percolating through it the water may lodge on the surface, increasing the tendency to sourness, and lowering the soil temperature by excessive evaporation. It is generally recognised that a sandy soil, with a slight admixture of clay, is the best of all soils for irrigation.

Climate and Irrigation.—As would be expected, irrigation is more beneficial in dry than in moist climates. It is useless, may even be injurious, in a wet season. The best results are obtained in a genial climate.

Crops for Irrigation.—Where moisture is deficient, all crops will be benefited by prudent irrigation. For certain crops, however, it may be employed with greater advantage than for others. In the British Isles irrigation is confined almost entirely to meadows; but in other warmer and drier countries it is used largely for other crops upon arable land.

¹ Stephens’s *Prac. Irri.*, 82.

² *Ibid.*

Rye-grass and lucerne are especially suitable for artificial watering, while, to a certain extent, turnips and grain crops will—in their earlier stages—in a dry year be benefited by a moderate amount of irrigation.

Water-supply.—This may determine not only the practicability but the profitability of irrigating any particular piece of land,—whether sufficient water is obtainable from streams or canals to water the land by gravitation; or whether the supply has to be obtained or applied with the additional cost of pumping. Provided the water-supply is available, the situation or level of the land in relation to the source of supply will determine the cost of applying it.

In a given locality, there is seldom any choice of waters as to quality; but, generally speaking, river waters are the best for irrigation purposes: they contain more suspended matter than the waters of canals, springs, wells, tanks, or reservoirs.

Quantity of Water Required.—No rule can be laid down on this point. The quantity of water required to irrigate an acre of land varies not only with the number of waterings, but with the kind of crop, the objects of watering, the nature of the soil, the humidity of the atmosphere, and the character of the season.

Half an inch of water, with a steady flow, is considered sufficient to irrigate an acre of wheat in the Northern States of America, where the water-rent averages from 4s. to 6s. an acre. But the unit in general use in the irrigated regions of the United States, is the "second-foot," or cubic foot per second—that is, a quantity of water equalling a stream 1 ft. wide and 1 ft. deep, flowing at an average velocity of 1 ft. every second.

The area of land which can be irrigated by a "second-foot" of water varies as widely as from 30 to 120 acres or more, according to the conditions of soil and climate, the methods and skill of applying the water, and the kind of crop and its requirements. Thus if a full flow of water is turned directly upon a hard, sun-baked, and unstirred soil, much of it will be wasted by running off the surface instead of sinking into the soil. And whatever tends to prevent either seepage

or evaporation will conserve water in the soil; also the water of irrigation will go further if applied directly to the roots of plants cultivated in rows than by wholesale flooding of the surface. Irrigated wheat generally gets three waterings, sugar-cane eight, and rice still more.

Even in countries where irrigation is most needed, it is found that the dependence on artificial watering is much lessened where the land is well subsoil-drained. Both the natural rainfall and the water artificially applied are then more fully made use of and better conserved in the depths of the soil, instead of much of it being wasted by running off the surface, as is always the case where there are any open drains and the water does not percolate downwards. With the deep reservoir in the soil itself, provided by under-drainage, not only is less artificial watering required, but the yield, and also the quality of the crop, is much improved.

It is interesting to learn from the annual Reports of the U.S. Geological Survey that, as irrigation extends, less and less water is required on many soils in the arid and semi-arid regions of the Western States, this being due perhaps to a general raising of the moisture in the ground, or to a clogging of many points of escape. The result is that less water per acre is used and needed on the older lands than on the newer. Few countries, where irrigation is at all needed, are possessed of an unlimited water-supply; in most cases the supply is strictly limited, and cannot by any means be increased, except at a prohibitive price. Hence the need of water-economy in irrigation, and the benefit which must accrue from any method which will double "the duty of the water," or by which it can be made to water two acres where it formerly sufficed to water only one.

Sewage Irrigation.—By means of irrigation applied to meadow-land, the sewage of towns is now, in many cases, turned to excellent purpose. The Edinburgh sewage meadows afford a good example of what may be done in this way. From permanent grass, cut four or five times a-year, a gross yield of nearly 40 tons per acre is obtained per annum; while land sown with Italian rye-grass

affords five or six cuttings, and perhaps as much as 60 tons of produce in one year. The grass is used by cowfeeders in Edinburgh, and brings from £20 to £35 a-year per acre.

There are many sewage farms in England, mostly owned and worked by Borough Corporations, where the various methods of sewage treatment may be usefully studied, as well as the systems of cropping and of farm management pursued. The crops grown on these farms are mostly for the supply of green food for horses and cows, and of vegetables for market. Cow-keeping and pig-feeding are also extensively practised on some of the sewage farms.

It has been found, by a comparison of the milk from cows fed on ordinary meadow-grass and on grass from a sewage farm, that in the latter case the keeping qualities both of milk and butter were lowered. This difference, however, was more marked in spring than in the latter part of summer. And the idea that the produce of a sewage farm is injurious to health is contradicted by the experience gained at Edinburgh and elsewhere. No ill effects have been traced in the health of persons living around sewage farms well conducted; nor is there any proof that vegetables grown thereon are in any way inferior to vegetables grown with ordinary manure; on the contrary, there is abundant evidence that such vegetables are particularly suitable for the food of both man and beast, whilst the milk given by cows fed on sewage grass is perfectly wholesome.

Systems of Irrigation.

The systems of irrigation best known are bed-work irrigation, catch-work irrigation, sub-irrigation, side-irrigation with open drains, irrigation by pipe and hose, irrigation by surface pipes, flooding or swamp irrigation, warping, sewage irrigation, and irrigation by watering-carts, water-drills, &c.

Bed-work Irrigation.—This system is applied only to grass land that is nearly level on the surface. The ground is laid out in sloping beds or ridges, the ridges varying in width from 10 to 12 feet, according to the nature of the soil and lie of the land. The supply of water is introduced by a main feeder at the

highest points, so that by gravitation it may be distributed to all the irrigation channels.

Catch-work Water-meadow.—The catch-work form of water-meadow is well adapted to pastoral farms. It is applicable to an irregular surface of grass; and the irregularity being varied, no description can be given which would have a universal application. "To give exact directions for the formation of catch-work," remarks Stephens, "is beyond the ingenuity of man; for no two pieces of land are precisely alike, which renders it impossible for the irrigator to follow the same plan in one field that he has done in another. Each meadow, therefore, requires a different design, and the construction to be varied according to the nature of the ground and the quality and quantity of the water." It may be useful, however, to describe the system as applied to patches of smooth grass near brooks.

In fig. 287 the ground is supposed to fall from *a* to *d* and from *c* to *v*; and *o p* is a ridge of ground falling from *o* to *p*, from which the ground declines on the right to *q t*, and on the left to *v z*. A main conductor, *a b*, cut at the highest part of the ground, conveys the water down the incline from *a* to *b*, where it is divided into the two feeders *c* and *d*, feeders being channels cut widest at their origin, and coming at their extremities to a point, to impel the water in them to overflow and run to a lower level. In the overflow from *c* to *d* the water finds its way to *e f*, which collects what comes to it as a drain; but it is in its turn a feeder, and disposes of its surplus water down the descent to *g h*, which sends it to *i*, which sends it to *k*, and which lastly sends it to a main drain *u m*. Part of the water finds its way to the drain *n*, which conveys it to the main drain at *m*. In like manner the water issues out of the main conductor *a b* into the sub-conductor *o p*, from which it flows, being a ridge or watershed to the right to the feeders *q, r, s, t*; and to the left to the feeders *v, w, x, y*, and *z*; to all of which feeders *l u* acts as a main drain. From the horizontal position of *c d*, the water will impart most of its sedimentary constituents to the ground between it and *f e*, and by the time the water has reached

k, very little foreign matter will be left in it, so that the grass in the upper part of the meadow will be better nourished than in the lower; but the perpendicular sub-conductor *o p* carrying the water from the main conductor *a b* directly to all the feeders in connection with it, the water bestows equal advantage upon every portion of that part of the meadow. Each feeder may supply water for 30 feet of ground in breadth, if the descent is gradual; but if sudden, the breadth may be increased to 40 feet.

Regulating Water-flow.—Where water flows with unequal velocity, whe-

ther in conductors or feeders, *stops* are placed in them to retard the velocity. The stops are made of various materials—of projections of the natural turf left uncut, of pins of wood driven into the middle of the channels, of sods pinned down, of one stone, of stones piled in a heap, and of short boards of wood thrust into the edges of the channels at an angle. But all the stops enumerated are objectionable. Pins collect straws and sticks brought by the water; stones and turfs cause holes in the channels by the water falling unequally over them; and notch-boards injure the edges of the feeders,

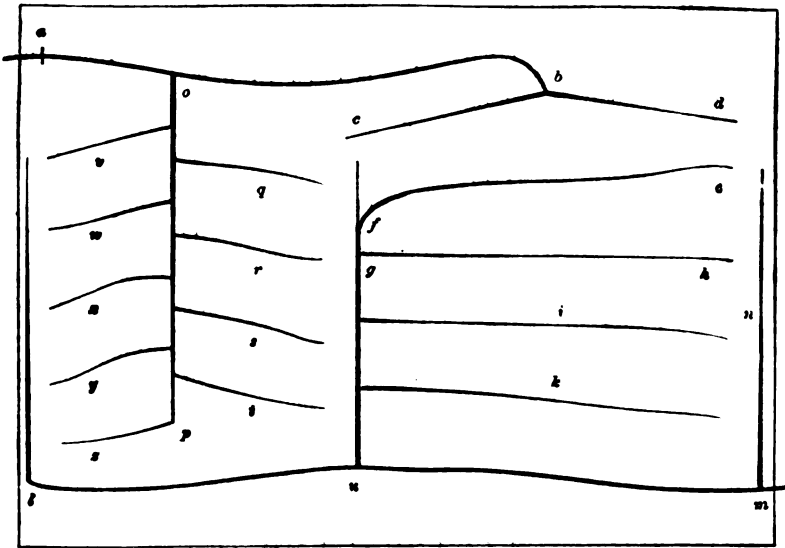


Fig. 287.—Catch-work water-meadow.

besides causing deep holes by waterfalls. The best stop consists of a piece of wood forming two wedges with their bases united, which, when placed firmly at the bottom between the edges of a conductor or feeder, the water flows over in an unbroken mass, with a retarded velocity. A number of such stops of different breadths should be kept to fit any size of channel. No stops are required where the water directly overflows from *b c* and *b d* (fig. 287); but where it is guided from the main conductor *a b* to *o* down the steep sub-conductor *o p*, one stop is requisite at each of the feeders *q*, *r*, *s*, *t*, and *v*, *w*, *x*, *y*, *z*.

Where the ground falls continuously from one patch of grass to another, the water should be conveyed in a lead from the lowest main drain as from *m* of one water-meadow to the main conductor of a lower meadow.

Liquid Manure for Irrigation.—Where there is a scarcity of water, liquid manure may be poured into the main conductor to enrich the irrigation. Many are of opinion that liquid manure gives better results applied in this way than when it is applied directly upon bare soil.

Side-irrigation.—For the system of side-irrigation with open drains, open

drains are formed in the field, perhaps from 10 to 12 yards apart. These open drains communicate with drainage canals, into which the irrigation is admitted, and from which it passes into the open drains, where it collects till it rises to the level of the surface or very near it, according to the extent of watering desired. Sluices are then opened in the canal and the water is withdrawn.

Other Methods.—Irrigation by pipe and hose, and by rows of stationary pipes, hardly needs description here, any more than irrigation by the water-cart and water-drill.

Swamp Irrigation is of little value in the United Kingdom, except for growing water-cress.

Warping is not capable of extensive application on the British Islands, yet in certain cases it has been carried out with advantage. It consists of the repeated flooding of low-lying river or tidal land. The object here is not merely to water the land, but also to enrich it, and probably raise its level by allowing the water to deposit the alluvial matter which it has held in suspension. The water to be employed in warping is admitted to the land to be warped by a canal from the sea or river, sluices being provided to regulate the admission and discharge of the water. The

land to be treated is hedged in by water-tight banks, to confine the water to the fixed area. Where warping can be carried out effectually, it will most likely enhance the fertility of the land to a remarkable extent.

Cost of Irrigating Land.—Will it pay? This is the practical test of the needs and benefits of irrigation in all countries. In a dry, warm, and forcing climate, where vegetation responds amazingly to the application of water, and no crop can be reckoned on with certainty without artificial watering, a large initial outlay per acre may be profitably expended in providing a permanent water-supply, and in forming channels for its distribution. In such countries the "water-rent" per acre is often as high as the rent paid for the use of the best farm lands in England and Scotland. But in our climate artificial watering will not pay as a regular and general practice, although it may be profitable at times. As a rule, it costs more to carry water on to land than to carry it off; and the mere distribution of the water in bed-work irrigation in this country has, in most cases, cost more than it would do to drain the land. Bed-work may cost anything from £3 to £12 an acre. Catch-work irrigation costs only as many shillings.

LIMING LAND.

The liming of land is a practice of long standing in this country. In later times it has not been so largely followed as formerly, owing perhaps to the increased cost of labour, the increased use of artificial manures, and the lower prices of farm crops.

Sources of Lime.—Lime, or, to be more definite, "oxide of calcium," is met with in nature chiefly in the form of the compound carbonate of lime, otherwise known as limestone, chalk, marl, &c., also as phosphate of lime or coprolites, sulphate of lime or gypsum. It is likewise present under other forms, as in *basic slag*, a by-product in the manufacture of steel, which contains

about 45 per cent of lime (one-third to one-half of it in the caustic state), and is now very largely used as a phosphatic manure.

Form in which to apply Lime.—The most useful form of lime for land is that known as burnt lime, lime-shells, quick-lime, or caustic lime, obtained by burning either chalk or limestone in a limekiln. The lime added to soils in the form of sulphate in all dissolved manures does not serve quite the same purpose. Free lime as it exists in quick-lime or slaked lime, also in chalk, marl, and basic slag, acts as a base for combining with the acids produced naturally in the soil; whereas in superphosphate,

dissolved bones, or gypsum, the lime is already saturated with strong acids, and superphosphate especially may demand more lime from the soil to neutralise its excess of acid; so that the lime in these "artificial" is no longer capable of acting as a base. Besides, the carbonate of lime is more easily decomposed by the soil organisms than any other lime compound, and is therefore more available and useful.

Action of Lime.—Lime when applied to the soil acts in several ways, both chemically and mechanically. When the carbonic acid and water are driven off by heat it becomes a strong alkaline earth, and in this caustic state combines with the oxygen and carbonic acid set free by the decomposition of organic bodies present in the soil. The decay of organic matter is thereby quickened. It also breaks up the compounds of inorganic matter which have become dormant or insoluble, and by combining with the elements of which these are made up, renders them active or soluble in water, and so available for plant-food. It combines with and neutralises or utilises free or injurious acids which are present in a soil, and which render it sour, thereby changing its character, and making it sweet and mellow. It is, moreover, itself also a direct plant-food.

Lime acts mechanically inasmuch as it changes the texture of a soil, opening and rendering more friable stiff loams and heavy clays, and giving cohesion and firmness to loose and sandy soils.

Benefits from Lime.—The result of these changes effected by the use of lime are an increase of produce, grain of better quality and colour, stiffened straw, sweetened herbage, and an earlier harvest. Lime often almost entirely changes the herbage of pasture-land, notably when applied to rough grass or heath, which it kills out to make room for a higher order of vegetable growth.

Injury from Imprudent Liming.—But there are disadvantages attendant upon the too free use of lime. By its action we must look upon it as a stimulant rather than as a manure. Indeed, if it were regularly applied to land without other manures, the soil would soon become exhausted. This well-established

character of lime has been aptly expressed in the saying that "lime without mulch enriches the father and impoverishes the son."

Time for Applying Lime.—Before green crops found a permanent place in the rotation of the farm, the most convenient time for applying lime was to the bare or summer fallow in spring. It is now generally applied to the leas in autumn or winter before they are broken up. In some counties the custom is to spread it on the land after the turnip crop has been removed. Others spread the lime when the land is being prepared for the turnip seed, or in small heaps immediately after the turnips are sown, and consider that the after-cultivation of the crops will mix the lime with the soil. These three methods, however, are objectionable, as by placing the lime into such close contact with the manure, the latter may be seriously dissipated.

Lime Dissipating Plant-food.—Caustic or quick lime applied in excess to newly manured land is apt to liberate a greater quantity of the most valuable ingredients of the food of the plants than the crop can immediately make use of. On this account much plant-food may be lost by being washed into the drains, or evaporated in the form of ammonia or other volatile gases.

Lime and Nitrifying Organisms.—A new light has been thrown upon the process of liming land by the growth of the science of Bacteriology. Towards the close of the seventh decade of the nineteenth century scientists became aware of the existence in the soil of what are now known as Nitrifying Bacteria, minute living organisms, which later research has shown to play a part of the highest importance in the preparation of plant-food in the soil. In order that these bacteria may flourish in the soil there must be present some suitable base to unite with and neutralise the acids they produce, and lime is the base which best fulfils this essential function. It has long been known that lime loses much of its usefulness when it sinks into the lower layers of the soil. The reason for this, no doubt, is that, as the nitrifying bacteria confine their operations mainly to the surface

soil, it is there that lime is of the most service to these laborious workers.

Lime for Sandy Soils.—The late Dr Voelcker showed clearly the importance of liming poor land before dressing it with dung or other manure.¹ "The most liberal application," he says, "of farmyard manure of the best quality never produces so beneficial and lasting an effect on poor sandy soils as when they have been previously well marled or limed. There are some soils which swallow up manure with, so to speak, an insatiable appetite, without ever feeling the better for the manure,—they are appropriately called very hungry. On all such soils much manure is wasted, or the most is not made of it, if previously to the application of farmyard manure, guano, &c., the land has not received a good dose of lime. . . .

"Lime not merely acts beneficially on sandy soils in a direct manner, by supplying a deficient element of nutrition, but also because it preserves in the soil the more valuable fertilising matters, which, like salts of potash or ammonia, rapidly filter through sandy soils, unless a sufficient quantity of marl or lime has been previously applied to the land. By these means the bases of the more valuable saline constituents of rotten dung or of guano are retained in the land, whilst the acids filter through it in combination with lime—a constituent which is, comparatively speaking, inexpensive.

Lime and Soluble Phosphates.—"The presence of much or little lime in a soil has also a powerful influence on the changes which soluble phosphates, or manures containing soluble phosphates, undergo in contact with the soil. It is a curious and apparently anomalous circumstance, that on sandy soils, and on all soils deficient in lime, concentrated superphosphates, rich in soluble phosphate, do not produce nearly so beneficial an effect upon root-crops as upon calcareous soils, or upon soils containing even a moderate proportion of lime.

"When applied to root-crops upon sandy soils greatly deficient in lime, a concentrated superphosphate produces a smaller crop than a manure containing

only one-fourth the percentage of soluble phosphate. When this fact was first brought under my notice I ascribed it to prejudice, or accidental and unobserved circumstances; but direct experiments and an extended personal experience have shown me that there is no mistake about this matter. The true explanation no doubt is, that the excess of acid soluble phosphate in a concentrated superphosphate is not precipitated as efficiently in a soil deficient in lime as it is in land containing a good deal of lime.

"Acid compounds are extremely injurious to vegetation, even in dilute solutions; and hence concentrated superphosphates used in large quantities, say at the rate of 5 to 6 cwt. per acre, do positive injury to root-crops, and more moderate applications of 2 or 3 cwt. per acre produce a less favourable result on sandy soils, and on all land poor in lime, than the same amount of superphosphate poor in soluble phosphate. Indeed, the experience of light-land farmers in districts in England where the land is deficient in lime goes to prove that on land of that description it is better to apply bone-dust or precipitated phosphate, or phosphatic manures containing no soluble phosphate, to root-crops, than to use superphosphate, or similar artificial manures containing a large proportion of acid soluble phosphate of lime."

Lime in Drainage Water.—The composition of drainage waters invariably shows that about four-fifths to five-sixths of the total mineral matter carried off in the drains, from unmanured ground, is lime, mainly in the form of carbonate, but also as sulphate, and in relatively smaller yet considerable amounts as nitrate, of lime.

Lime-loving Crops.—While lime is needful for all crops, some of them—clover, vetches, peas, beans, turnips, and mangold in particular—require it more than others.

Lime as a Preventive of Crop Diseases.—Lime is most useful as a preventive of diseases which attack crops, such as clover-sickness and finger-and-toe in turnips. In many parts of the country more lime is now used for the checking of finger-and-toe in turnips than for all other purposes combined.

Effects of Lime on Grass Land.—

¹ *Jour. Roy. Agric. Soc. Eng.*, sec. ser., xiv., part ii., 546, 547.

Lime, either by itself or in compost, often plays a large part in the restoring of decaying pastures. At Rothamsted, the mean of three years' (1885-87) ex-

periments with lime on grass land gave the following result as to weight of produce, and as to botanical composition of the herbage:—

	Hay per acre.		Botanical Composition per cent.					
			Gramineæ.		Leguminosæ.		Other orders.	
	Un-limed.	Limed.	Un-limed.	Limed.	Un-limed.	Limed.	Un-limed.	Limed.
Unmanured (one year only)	cwt. 18.6	cwt. 18.9	76.0	69.0	7.1	16.0	16.9	15.0
Complete minerals, following ammonium salts	23.8	28.7	72.8	67.7	11.7	20.1	15.5	12.2
Complete mineral manure	26.1	33.1	64.3	48.4	22.0	41.8	13.7	9.8
Mineral manure without potash	17.0	16.7	60.6	7.8	7.5	8.1	31.9	20.8
Complete minerals, following nitrate of soda	12.4	25.6	67.4	53.8	3.2	35.3	29.4	10.9

Lime for Hill Pasture.—In the notes on improving hill pasture in this vol. (p. 343) information is given as to the application of lime to permanent pasture on sheep farms, and also as to its effect on herbage.

Durable Effects of Liming Land.—Although compensation for liming under the Agricultural Holdings Act is limited to applications made within the last seven years, where a liberal dressing has been given the good effects will be visible, especially on pasture land, for 20 or even 30 years. But this only goes to show the wisdom of applying very small doses at frequent intervals, instead of 5 or 6 tons an acre to last for the term of a 19 years' lease or longer, as was the rule until the last few years. The farmer of to-day does not lime land to benefit posterity, but for immediate profit; and even if he were allowed a scale of compensation extended to 20 or 30 years, he would still be a loser by liming in heavy doses at long intervals, because every succeeding year a larger proportion of the lime in the soil is lost by sinking in the soil, and by solution and drainage. On the experimental fields at Rothamsted it has been found that natural agencies, chiefly the carbonic acid and water in the soil, are removing the calcium carbonate that has been

introduced into the surface-soil at the rate of about 1000 lb. per acre per annum.

Over-liming.—In former times, when the properties and functions of lime were not so well known as now, the over-liming of land occasionally occurred. Excessive liming without sufficient other manurial dressings will certainly impoverish land. It is now also well known that just as judicious liming promotes the growth of nitrifying bacteria, so over-liming will destroy these useful soil-organisms.

Burning Lime.—For use on land as for mortar, lime is burned in kilns, and conveyed to the farm or field in the form of shells. Many farmers who have limestone within reach burn their own lime, using peat as fuel if it is to be had, and, if not, purchasing coal for the purpose.

Limeshells.—In preparation for burning, limestone is broken into handy lumps, and is packed in the kilns in alternate layers with coal or peat. From being a close-grained, hard, heavy stone, it is reduced to a porous, light, splintery cinder. One ton of limestone, when thus burned, yields about 11 cwt. of the cinder. The cinder is called *limeshells*, and is the state in which lime is taken to the farm. Being light, they are easily carted, though not safe to the skin to handle. The burning has the effect of driving off

water and carbonic acid from the limestone; of forming gypsum with the sulphur of the coal, and with the pyrites of the limestone; and silicate of lime with the silicious matter present in the limestone and the coal.

Limeshells have a strong affinity for water. They will extract it from the atmosphere and become in time slaked, which is the end aimed at in putting limeshells on the land in small heaps along the ridges.

Slaking.—The limeshells may be slaked instantaneously, however, by water being poured upon them, but this is not always practicable in the fields. Moreover, pouring water too quickly upon shells causes the lime to be gritty, and to contain many small lumps which refuse to be slaked. The spontaneous slaking, by simply leaving the limeshells exposed to rain and the atmosphere, is attended with the least trouble, but in effect it chills the surface and produces much gritty lime; and it gives sufficient time for much of the powdered lime to absorb carbonic acid from the air, and go back to the state of carbonate and loses its caustic properties.

One method of spontaneous slaking is to lay the limeshells in small heaps on the land, and to cover each heap lightly with a few spadefuls of soil. The heap is then soon reduced to a fine dry powder, whether rain falls in the interval or not, the lime getting enough of moisture from the soil and from the atmosphere to slake it; and if the small heaps have been laid out at regular distances apart both ways, the finely powdered lime can be evenly distributed over the whole surface of the field by means of a shovel, without further carting.

Dr Wilson of Carbeth states that, after trying various methods of slaking, he came to the conclusion that he got the best results by putting the shells in heaps of three or four tons. In this way he could make sure of getting a uniform mass of powdery caustic lime.

Lime absorbs about one-fourth of its weight of water; it increases from two and a half to three and a half times its bulk; and the powder has strong caustic and alkaline properties.

Composition of Slaked Lime.—The ultimate results are, that the slaked lime

consists partly of caustic lime, partly of carbonate of lime, partly of hydrate of lime, somewhat in these proportions in one ton:—

		Per cent.	Cwt.
Carbonate of lime		57.4	11 $\frac{1}{2}$
Hydrate of lime	{ lime water	{ 32.4 10.2	{ 42.6 8 $\frac{1}{2}$
		100.0	20 $\frac{1}{2}$

Ground Lime.—The plan of grinding the burned limeshells to a fine powder instead of slaking them is now largely adopted. Many still prefer the slaked lime, which is the cheaper form, and is usually purer. The ground lime, however, is specially suitable where small dressings are desired, as it can be spread very uniformly in any given quantity by manure-distributing machines. As already stated, all lime should be bought with a guarantee of quality; but in the case of ground lime this precaution is especially necessary.

Ground Limestone.—Limestone ground into powder without being burned is now also being used with excellent effect. Some trials took place in Lancashire in 1907 with ground unburnt limestone, ground burnt lime, and limeshells. The trials were carried out on four different farms, and the results all over were in favour of the ground unburnt limestone. The quantity of "shell" lime applied was 1 ton, costing 14s. 2d.; of ground burnt lime 1 ton, costing 22s. 2d.; and of ground unburnt limestone 1 $\frac{3}{4}$ tons, costing 13s. 8d.

Spreading Lime.—Frying-pan shovels are the best implements for filling carts with lime, and spreading it upon land. A calm day is chosen for the purpose; but in case of a slight breeze, the single-horse carts are placed to the windward of the heaps when being filled. The direction in liming should be against the wind, and the men should arrange themselves on the ridges so that the cart farthest down the wind takes the lead in spreading.

In spreading lime, the man walks along the middle of the ridge, and casts the shovelfuls right and left from the middle towards the furrows, which will become, by ploughing, the crowns of the

¹ Johnston's *Use of Lime in Agric.*, 44.

future ridges. The man who can cast the shovelfuls with either hand will spread lime better than one who is right- or left-handed only.

The lime should be spread *evenly over the surface*; but to suit irregularities in the character of the soil, it may have to be spread thicker on one part of the field than another. On light knolls it is spread thinner than in hollows, where the soil is deeper or stronger.

Whenever rain falls, liming should be discontinued.

Care of Men and Horses in Liming.—In the operation of spreading lime it is advisable to put a cloth over the horse's back and harness; while the men should cover their face with crape, to save the eyes, lips, and nose. The horses, whenever loosened from work, should be wisped down and brushed, to free the hair of lime; and if the men feel a smarting in their eyes or nose, sweet thick cream is the best emollient to apply. All this may be avoided by handling the lime as directed under "Slaking," p. 364.

Quantity of Lime per Acre.—The quantity of lime applied depends mainly on the nature of the soil, the lighter soils requiring less, and the stronger greater quantities. On light turnip soils, some give from 3 to 5 tons per acre, whilst others use up to 7½ tons. As much as 20 tons have sometimes been applied with advantage to one acre of wheat-land. On weak moory soils, 3½ tons are enough to commence its improvement.

Frequent Liming.—Formerly the prevailing custom was to apply large dressings of lime at long intervals, most likely once in fifteen or twenty years. The general custom now is to give small or moderate applications at short intervals—perhaps from 2 to 5 tons at intervals of from five to ten years. This is unquestionably a marked improvement upon the old plan; but it is only a sort of "half-way" house, and the most up-to-date farmers prefer to lime at still shorter intervals, giving doses not exceeding 1 to 2 tons per acre.

Ground lime is most generally applied by a manure distributor at rates varying from 5 to 30 cwt. per acre.

This system of frequent applications of small quantities employs the lime

much more economically, and the effect upon the land is evenner and altogether more satisfactory. Lime has a strong tendency to sink in the soil, and when a large dressing is applied at one time, a good deal of it may be lost by sinking into the subsoil before it has had time to exert its beneficial influence upon the upper stratum.

Covering in Lime.—In view of the tendency of lime to sink in the soil, it is desirable that it should be covered in as lightly as possible. If the lime is applied on lea, as it now usually is, the land should be ploughed with a shallow furrow. If the lime is applied on the fallow or root break after ploughing, a turn of the harrows will suffice for the first covering, and the first furrow thereafter should be shallow.

Weight of Lime.—Lime weighs from 75 lb. to nearly 1 cwt. in a bushel, which indicates that it ought not to be laid on by measure alone, but by measure and weight, giving preference to the lightest weight.

Limestone.

The lime used in the agriculture of this country is derived chiefly from the mountain-limestone of the carboniferous series, as also from the coal-formation. The rock forms a broad belt across the centre of Scotland, along the centre of England, and in the whole of the centre of Ireland. Lime in Scotland is mostly derived from the coal-formation, where it is associated with shales, sandstones, and ironstones. In Ireland large beds and knolls of limestone nodules, in the form of gravel, are found in many districts. The gravel, when laid upon the land, acts as lime in the course of time; and it affords a very ready means of reclaiming drained bogs, and of reducing their vegetable into earthy matter.

Composition of Limestone.—The composition of some good limestones for agricultural purposes is here given:—

	Carlisle.	Cockermouth.	Kilnhead.	Relig.
Carbonate of lime	93.91	94.86	95.89	93.97
Sulphate of lime	0.85	0.23	0.32	..
Phosphate of lime	1.14	..	..	..
Carbonate of magnesia	2.06	1.26	0.54	1.32
Alumina and oxide of iron	1.63	0.73	1.20	1.57
Silica . . .	0.41	2.92	2.05	3.14
	100.00	100.00	100.00	100.00

Composition of Lime.—The composition of the limes obtained from the limestones mentioned above, with the exception of Relig, is as follows:—

	Lanarkshire, Carlisle.	Cumberland, Cockermouth.	Dumfriesshire, Kilnhead.
Lime	89.78	89.77	88.64
Sulphate of lime (gypsum)	1.45	0.38	0.51
Phosphate of lime	1.93	..	..
Magnesia	1.69	1.02	0.43
Alumina and oxide of iron	2.76	1.23	1.98
Silica in the state of silicate	0.70	4.92	3.39
Carbonic acid and moisture	1.69	2.68	5.05
	100.00	100.00	100.00 ¹

The percentages of quick-lime in the above analyses are exceptionally high. It is not often that a guarantee of 85 per cent can be obtained, but it should always be over 75 per cent, with not more than 4 per cent of magnesia.

Buyers of pretty large quantities of lime can usually arrange with the burners to use their best rock, and have it burnt in kilns cleaned out with special care. In this way lime of exceptional quality may be obtained. An extensive user of lime states that until he adopted this plan he often got deliveries showing less than 60 per cent of quick-lime.

Characteristics of Lime.—The purer lime is, the better it is considered for agricultural purposes: it is then said to be in the fattest and strongest state. Of the varieties of limes whose analyses appear above, it would seem that the Kilnhead is the best for applying to the land. Plasterers like fat lime, as it runs best and makes the strongest putty. When a considerable proportion of sand occurs, it is the better adapted for common building purposes, as it then requires less sand to convert it into good

mortar, and the natural union of silicious matter is much better than any artificial method of adding that can be devised. Of these the Cockermouth is the best for buildings.

Much magnesia in lime is hurtful to vegetation, and is therefore unsuited for the land; but it is a useful ingredient in lime intended for buildings under water, such as piers and docks, where it becomes very hard, and on that account is called hydraulic lime.

GAS-LIME.

Lime may be obtained from other than natural sources. The rubbish of old buildings afford it an effete state.

Gas-lime is procured from gas-works, and is used as a manure. The use of this substance is noticed in the chapter on Manures and Manuring in this volume. It is best applied to lea in autumn or early winter at the rate of from 2 to 4 tons per acre.

COMPOST.

A compost of lime and earth is a better top-dressing for grass land than either separately. This compost is usually made too weak in lime. The proportion should be one cubic yard of lime to three cubic yards of earth well mixed. But with labour scarce and dear the making of compost on a large scale would not likely pay the farmer.

The appearance of white clover, *Trifolium repens*, on top-dressing heathy soil with lime, is a well-known fact. Lime extirpates the corn marigold, *Chrysanthemum segetum*, but it encourages the red poppy, *Papaver rhæas*; and on sinking into strong clay it favours the growth of colt's-foot, *Tussilago farfara*.

¹ *Trans. High. Agric. Soc.*, July 1848, 299.

CARE OF IMPLEMENTS.

Before entering upon the tillage work of the farm, it will be useful to introduce some notes relating to the care of the implements and machines employed by farmers. As a rule, farmers are not so

careful as they ought to be in protecting their implements from injury, by exposure to the weather. Implements are used both within and without doors. Those used without doors may be divided

into those in use every season, and those used only occasionally. Implements frequently in use upon the soil cannot be otherwise than constantly exposed to the weather; and fortunately they are of simple construction, and are less affected than those of complicated construction, which are used for a short time at certain seasons.

The implement most frequently in use is the plough. Being now made of iron, it can withstand exposure. Harrows, also frequently in use and much exposed to the weather, are now made of iron. Not being required in winter, they are placed in the implement-house. The tines should be sharpened just before the commencement of the spring sowings. The roller being only occasionally in use, in rolling young grass and spring crops, and pulverising the soil in summer, is replaced in its shed whenever its services are no longer wanted. The small double mould-board ploughs, being used in spring and summer, should be placed in the implement-house before winter sets in, scraped clean of earth, and have the irons repaired.

There are few implements which receive less regard when not in use than scufflers and grubbers. They are often allowed to remain at the sides of head-ridges and corners of turnip and potato fields, perhaps the whole winter. Being made of iron, they do not suffer much from weather; but having many small parts—tines, coulters, wedges, screw-bolts—they are best preserved in the implement-house, after having been repaired.

When putting implements together after overhauling and cleaning, all screws and bolts must be carefully oiled or greased, so as to prevent the rusting together of these important parts when exposed to damp: if this is done systematically, no difficulty will be experienced in taking an implement to pieces at any time.

Delicately constructed machines—such as grass-seed sowing, drill-sowing, turnip-sowing—are seldom allowed to remain longer in the field than in use, but often remain unheeded at the steading for a considerable time. Instead of, as is often the case, being taken to the stackyard and covered with straw, they should be repaired, taken to pieces and cleaned, the

journals greased, and the separate parts stowed away in the implement-house. The small manual implements, turnip-hoes, spreading-graips, dung-hawks, hay-knives, scythes, if not placed in the implement-house whenever out of use, are liable to be lost.

Of all implements, carts receive the most neglect. Their axles are not greased, their bodies and wheels unwashed, holes in the bottom or sides get enlarged, and the tire of a wheel becomes loose, till some day it flies off, to the risk of breaking down the felloes. The threshing-machine should be cleaned out every time a different sort of corn is threshed, otherwise samples will be impure. The gudgeons are oiled every time the mill is in use. Wherever a repair is required, it should be done immediately, otherwise a serious and expensive fracture may ensue.

Holes in sacks and in barn and chaff sheets should be instantly repaired by patching and darning; and a broken mesh in a riddle or a hole in a "wecht" or basket should be at once repaired.

Implement-house.

The fitting up of the implement-house, for the accommodation of the finer and smaller implements, should be so arranged as to have the floor unencumbered, and give free access to every implement required at a time. To effect this most easily, the house should extend from the floor to the roof. The floor is flagged to prevent rusting of iron in the implements. A wooden floor should be placed half-way between the ground and roof to form a loft, covering only two-thirds of the area of the house, and having one trap-stair to ascend to it. Both floors contain a large number of things, while the height to the roof admits of long forks, shafts, feering-poles, &c., being put into a corner.

Wheels, short shafts, and angular pieces of iron are best placed against a wall upon strong nails. Articles of length, as sowing-boxes, are best supported against a wall upon brackets. Small articles of iron and other material are best kept upon shelves. Hand-hoes and weed-hooks are best placed in framed stands. Scythes are best suspended from the balks. The bodies of small ploughs,

grubbers, and scufflers should be placed along the foot of the walls.

If every implement were put into its own place at the end of its season, confusion would be avoided in seeking for them; and many more articles find room in the implement-house when well arranged, than when things are put down anywhere, without regard to order.

A complete set of spanners to fit the various nuts on the implements should be mounted on a board fixed to the wall of the implement-house in a conspicuous position. A spanner after use should be at once replaced in its proper position on the board. Unless this is done, much valuable time is usually lost in hunting for spanners when wanted.

A good working set of joiners' tools, with a few files, cold chisels, &c., also a strong bench, should find a place in the implement-house, so that any small re-

pairs can be readily and quickly executed. An iron vice fitted to the bench is a very useful tool.

The cart-shed forms a good store for large implements; and were cross-beams put upon the wall-heads, they would contain many others. Ladders may be suspended horizontally along the inner walls of the cart-shed.

Neglect of implements may fairly be imputed to the steward. Were he to give strict orders that every implement out of use shall be put into the implement-house, that every one may know where to find it when again wanted, and to see that his orders are obeyed, there would be no waste of time in seeking for anything—there would be no loss of implements or parts of them—and the implements themselves would last much longer, to the manifest advantage of the farmer, and to the steward himself in the long-run.

PLOUGHS AND PLOUGHING.

THE PLOUGH.

The plough serves the same purpose to the farmer as the spade to the gardener. Both are used to turn over the soil with a view to its preparation for the reception of the seed.

Digging and Ploughing.—The operation of the plough upon the soil is to imitate the effect of the spade upon it; but the plough being too large and heavy to be wielded by hand, it is not so fully under man's control as is the spade. The ploughman is obliged to call in the aid of horses to wield it, and through their means, in combination with harness, he can command its motions effectively. Turning over the soil with so very simple an implement as the spade seems an easy operation; but the act of digging is neither simple nor easy, requiring every muscle of the body to be put in action, so that any implement to imitate that action perfectly would be obliged to have a very complicated structure. This would be the case even were

the machine fixed to a spot; but it is a difficult problem in practical mechanics to construct a light, strong, durable, and easily moved implement, which shall attain a complex result by a simple action. The modern plough is an implement possessing these properties to a certain extent, and is the most convenient implement as yet designed for the purpose.

Construction of the Common Plough.—The common plough used in this kingdom is made either wholly of iron, or partly of wood and partly of iron. Formerly it was universally made of wood and iron, but now almost as universally of iron alone. It is now made so, because iron withstands the changes of weather better than wood—a desirable property in any implement that must necessarily be much exposed to weather—and because, when old, iron is worth something, whereas ash timber is now scarce, dear, and worthless when decayed,—another advantage being, that iron implements are not so clumsy as those made of wood. An ordinary two-horse wooden plough with iron mountings weighs 14

stones imperial, and an iron one for the same work 15 to 20 stones.

Varieties of Ploughs.—Two varieties of ploughs, Small's and Wilkie's, were originally used in Scotland, and from these nearly all the forms now in use have been derived. The varieties to be found throughout the country are almost

innumerable, most implement-makers having several patterns of their own, while in recent years American ploughs with short concave mould-boards have come largely into use.

Ordinary Scottish Plough.—Fig. 288 is the *furrow-side* elevation of the ordinary Scottish iron swing-plough. The plough-

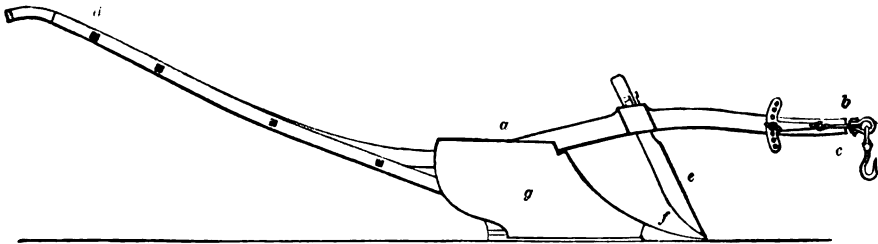


Fig. 288.—Furrow-side elevation of a Scottish swing-plough.

- | | | |
|--------------------------|------------------------|------------------|
| a b Beam. | a d Stilts or handles. | f Sock or share. |
| c Bridle, with its hook. | e Coulter. | g Mould-board. |

man holds and guides the implement by the *stilts*. The *bridle*, muzzle, hake, or clevis, with the hook, is that part by which the horses are attached to the beam. The *coulter* is the cutting instrument that severs the slice of earth or furrow from the firm land. The *sock* or share severs the slice below from the subsoil. The *mould-board* receives the slice

from the sock, turns it gradually over, and deposits it continuously at an angle. The coulter has a sharp cutting edge in front, and is slightly inclined that it may cut the cleaner.

Fig. 289 is the *land-side* elevation of the same plough. The *land-side plate* presents a straight broad surface to the firm land, and prevents the earth falling

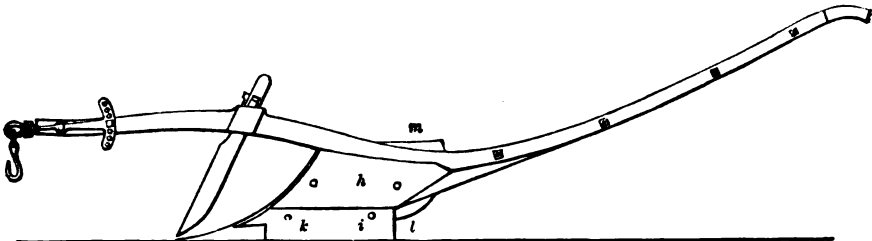


Fig. 289.—Land-side elevation of a Scottish swing-plough.

- | | | |
|--------------------|----------------------|-----------------------|
| h Land-side plate. | k Onset of the sock. | m Ear of mould-board. |
| i Sole-shoe. | i Heel. | |

within the body of the plough. The sole-shoe supports the plough, and slides upon the firm subsoil below. The attachment of the sock is with the lower end of the head of the plough, which is concealed in the figure, and which is fixed to the beam by its upper end. The ear of the mould-board prevents the earth falling into the bosom of the plough on that side.

Fig. 290 is a plan of the same plough.

The lines of the body of the plough on the land side are in one plane from the bridle to the end of the great stilt. The head of the coulter is fastened in a socket in the beam by means of iron wedges. The rake of the coulter varies from 55° to 65°. In the mould-board the upper edge is straight, and the breast is formed on the lines of a screw, or a plate twisted about itself, the fore part of which is truncated. The sock is

pointed, with a feather having a breadth of at least two-thirds the breadth of the furrow, and its cutting edge lying about as low as the plane of the sole. The neck of the sock is prolonged backward, joining and coinciding with the curve of

the mould-board at its truncated end. This plough cuts a furrow-slice of 10 inches in breadth by 7 inches in depth, leaving the sole open, level, and clean. This width and depth are pretty near the standard size of furrow for two-horse

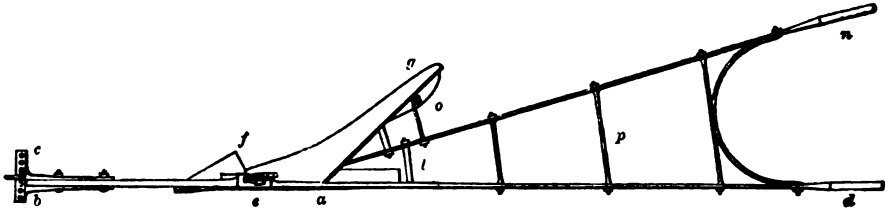


Fig. 290.—Plan of a Scottish swing-plough.

b d Straight line of body.
a b Beam.
c Bridle.
d Great stilt.

a Little stilt.
e Head of coulters.
f Feather of sock.
g Ear of mould-board.

l Heel.
o Bolts fastening the mould-board to the little stilt.
p Stays to support the stilt.

ploughing on ordinary soils, and these proportions are the best adapted for the ends in view where a greater or lesser furrow-slice is desired.

Modern Scottish Plough.—The general differences between the modern

Scottish and English ploughs are that an English plough has usually two wheels and chill-metal shares, while the Scottish has no wheel, or at most only one, and has wrought-iron shares. Less skill is required to hold a plough with two

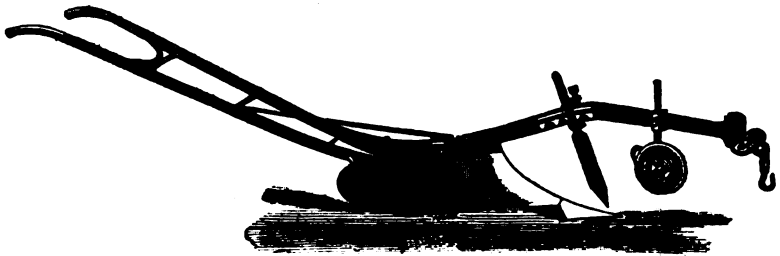


Fig. 291.—Sellar's modern Scottish plough. (Side view.)

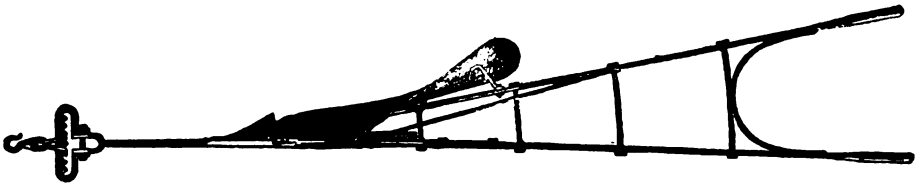


Fig. 292.—Sellar's modern Scottish plough. (Vertical view.)

wheels; but in skilled hands the plough is, perhaps, more useful and more controllable without wheels. The main reason, no doubt, why Scottish farmers have adhered so largely to the use of the wrought-iron shares, is that their soil is of a very variable and stony nature, for which the chill-metal shares are not

quite so suitable. They cannot be so easily adapted to stony and unequal soil as the wrought-iron shares, which can be altered by any country blacksmith to suit stony or clayey land, and to cut a rectangular or high-cut furrow of any shape as desired.

Figs. 291 and 292 represent the side

and vertical views of Sellar's modern Scottish plough. Fig. 293 represents Sellar's new movable-point plough. The chief

peculiarity in this plough, which is widely used, is that the point of the sock or share is separate from the

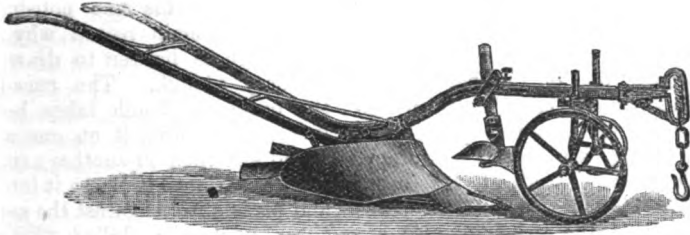


Fig. 293.—Sellar's movable-point plough.

feather, and is movable (fig. 294). It can be pushed forward as it wears, and, being made of steel, is very durable.



Fig. 294.—Movable point on Sellar's plough.

English Wheel-plough.—Fig. 295 gives a furrow-side view of Ransome's wheel-plough, one of the most improved of modern English forms. It is fitted with two wheels of unequal size on the front part of the beam, one of which is intended to run on the top of the ground, and the other at the bottom of the furrow. By means of these the width

and depth of the furrow-slice are regulated, so that the plough is kept steadily at the one place, and thus the draught is made easier for the horses, and less skill and exertion are needed on the part of the ploughman. Howard's well-known "Champion" plough is shown in fig. 296.



Fig. 295.—Ransome's "Newcastle" plough.

The use of a skim coulter of some kind is now universal with all the best farmers, and in many cases the old

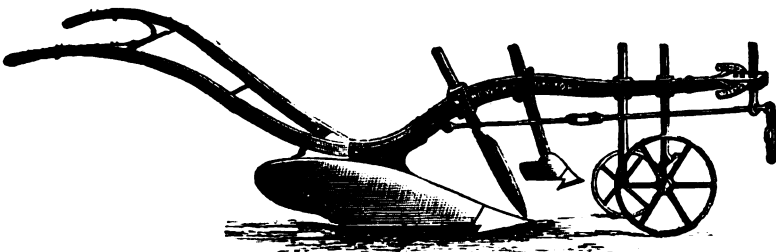


Fig. 296.—Howard's "Champion" plough.

"knife" pattern has been abandoned altogether—excepting in old tough lea ploughing—and a large-sized "skim" adopted. By its use a furrow-slice of "clean" earth is turned over for the next crop, and the surface-growth prevented from showing in the seams between the slices. The mould-board is

removable, so that a long or short one can be used according to the kind of work desired. In wheel-ploughs the stils are shorter and the beams longer than is the case with the swing-plough; and as the wheels really do the guiding part of the work, the handles could be dispensed with altogether, as is actually

done in the case of the "gang-ploughs" of America.

Chilled Ploughs.—In recent years there has been introduced into this country a modification of these latter ploughs—viz., the American chilled-steel plough. Fig. 297 represents Oliver's chilled plough, one of the best of the kind. This differs completely in appearance from the common ploughs of Britain in being very short and dumpy, though the beam is about the usual length. An important difference lies in the fact that the wearing parts are made of chilled steel, which takes on

an exceedingly fine polish, which greatly lightens draught by reducing friction, the common British ploughs having their breasts of ordinary steel or cast-iron only. This fine polish, however, is not the main reason why this type of plough is lighter to draw than the ordinary plough. The reason is that the ordinary plough takes hold of the furrow-slice, turns it on one axis so far round and then on another axis, and does not leave it until it places it into position, and presses it up against the next furrow-slice; while the chilled plough, which ploughs a broader furrow-slice, turns it

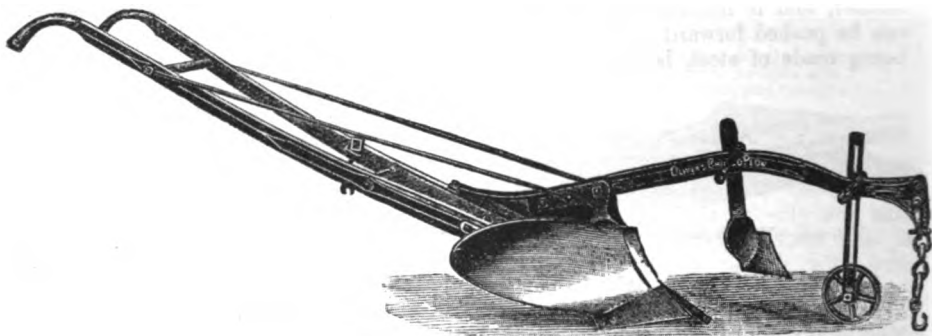


Fig. 297.—*Oliver's chilled plough.*

on a different axis altogether, and allows the furrow-slice to fall into its position after it has simply turned it past the perpendicular. In other words, the ordinary mould-board keeps hold of the furrow-slice and presses it into its place, while the chilled plough allows the furrow-slice, for the last half of the twist, to fall itself into position.

The short, wide-set mould-board has the effect of pulverising the furrow-slice as the plough goes along; and as it takes a great width in proportion to the depth, a large acreage can be quickly gone over. This sort of ploughing, of course, is most suitable for the moderate and lighter class of soils, and is not so well adapted for those of a heavy nature, though with the modern "digging" breasts now used it is eminently successful on all soils. Where a narrow furrow is desired the chill plough is not suitable.

Chilled ploughs are now made by several British firms, and the demand

for them is very large and still increasing. Fig. 298 represent the chilled plough made by Ransome, Sims, & Jefferies, of Ipswich.

Double-furrow Ploughs.—Double-furrow ploughs are used to a considerable extent. They are especially suitable for spring ploughing where a shallow furrow

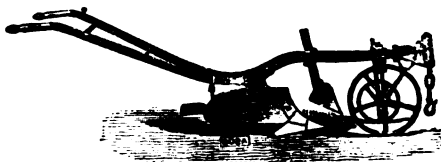


Fig. 298.—*Ransome's chilled plough.*

is desired. They expedite the preparation of land for sowing, and in a late spring this is a matter of great importance.

TURN-WREST OR ONE-WAY PLOUGHS.

For hilly land the turn-wrest plough is a most useful implement. It turns the furrow over in one direction, so that

by ploughing with it across steep land, the furrows can all be thrown down-hill, an advantage which every practical farmer will readily understand and appreciate. One of the best of these "one-way" ploughs is that represented in fig. 299, and made by Ransome, Sims, & Jefferies. This plough acts in the same manner as the common plough, when the mould-board is set as seen in the figure, the furrow-slice being turned over

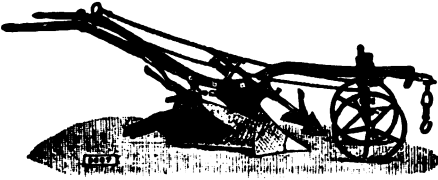


Fig. 299.—Ransome's One-way plough.

to the right hand; and on coming to the land's end, the other mould-board is brought into action on the left-hand side of the plough, and by it the furrow-slice is turned over to the left hand—where it is placed in the same position as was the preceding furrow-slice, which was turned to the right by the plough, while moving in the opposite direction. The even surface without open furrows, executed by this mode of ploughing, is highly

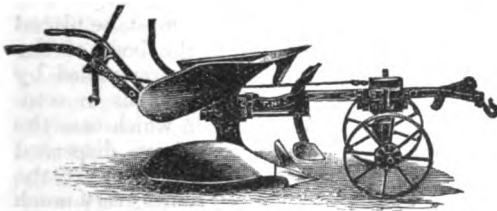


Fig. 300.—Cooke's One-way plough.

favourable to the action of reaping-machines in harvest. But, as has been indicated, its chief value is its adaptability for ploughing steep land. Fig. 300 represents another form of the turn-wrest—an excellent implement also, made by Cooke & Sons of Lincoln, and specially designed to turn over wide well-broken furrows.

DRILL-PLOUGHS.

Drill-ploughs will be noticed in the section dealing with root crops.

VOL. I.

MECHANICS OF THE PLOUGH.

The ordinary swing-plough, looked at as a machine, is a combination of some four of the "mechanical powers." The stilts with the body form a lever of the "first" or "second" kinds according to the way in which they are used. The share and front part of the wrest form an "inclined plane," up which slides the furrow-slice for a certain distance. The whole body of the implement forms a "wedge," as does also the coulter of itself; and the wrest or mould-board is to some extent a "screw."

Length of Stilts and Leverage.—In the case of the lever, every one knows from experience that the longer the "arm" or end at which the power or force is applied in proportion to the length of the other end, so much the more effective will be the "purchase" or ability to move a weight—as in the case of a labourer moving a stone with a crowbar. Applying this to the plough, we find that whether the heel of the sole-plate is used as a fulcrum (1st kind) in pressing down the handles, or the point of the share (2nd kind) in lifting them up, the longer the stilts are the more power shall we have to do so—i.e., to guide the implement easily. On the other hand, the length is limited by the necessity for easy manipulation of horses at the land ends, so that a medium of 6 or 7 feet is usually adopted between *a* and *d*, fig. 290. There are ploughs in practical use, however, with stilts 10 feet long.

Length of Beam.—On the other hand, the beam, *a b*, fig. 288, ought to be as short as possible. The horses are yoked to the end of it, and any unsteadiness on their part is communicated to the plough and must be counteracted by the ploughman, so that the less leverage power the animals have the more easily will the plough be held. The actual length is regulated by the "line of draught," which will be explained further on.

Body of Plough and Length of Wrest.—The body of the plough—including the coulter and share, as well as the wrest, cheek-plates, and sole-plate—is a combination of the inclined plane, wedge, and screw—the two latter of

these being in their mechanical principles simply modifications of the first—so that we may study their various actions as parts of one whole. It may be necessary to explain that the power exerted and work done in connection with an inclined plane varies according to the perpendicular height of the plane and the horizontal length. In other words, if we have two inclined planes of equal height, but the one double the length of the other, then a body will be pushed up the longer one with one-half the exertion required for the shorter—neglecting friction,—but the time occupied will be double. The wedge is simply two inclined planes put base to base, and the same reasoning is true of it—that is, the thinner the wedge or more gradual the slope, the more easily it is driven. Applying this to the plough, we find that the coulter, share, wrest, cheek-plates, and sole-shoe, all form more or less continuous parts of a large wedge or moving inclined plane. The weight or body to be moved is represented by the furrow-slice, both as regards its actual weight and its tenacity or toughness; and from what has been already said, and were it not that friction comes in as a disturbing element, it would be concluded that the best plan would be to have the wrest as long as possible, so as to secure the equivalent to a gradual incline. A wrest stuck out at a greater angle will use up more of the power of the horses than a wrest set at an easier angle; but as the friction is greater on a long than on a short mould-board, this factor has to be carefully considered. Moreover, if the wrest and body were too long it would make the implement unwieldy, and limit the leverage power of the handles, so that experience has taught that a medium of 30 to 36 inches is best, though ploughs with wrests about four feet long are in use.

Friction of the Earth.—The friction of the earth on the parts is a point of importance, and requires separate consideration. In its strictest sense the law of friction is that it varies as the weight or pressure, and that it is independent of extent of surface, but roughness or smoothness of surface influence

it very much. In practice in ploughing it is contended that this law does not fully apply. The mould-board of a plough is not simply a "wedge." It not only splits, but it also turns over. In the process of turning, a large portion of the furrow lies dead on the mould-board: the longer the mould-board the greater the mass of earth lying on it, and consequently the greater is the friction. With a short mould-board the furrow is turned quickly, and the friction is reduced to a minimum. Hence the lightness of draught of the chilled plough.

Wheels on Ploughs.—Wheels are put on ploughs for two reasons—viz., to keep the plough steadily at the one width and depth, and also to lessen the friction. In fig. 295 the front end of the beam is elongated a little, so as to allow of fitting on two wheels, whereby the former purpose is attained. There is nothing that tires out horses so quickly as jerky irregular work, a trouble that is obviated by these wheels, or even by the use of one alone running on the surface. More is necessary, however, for lessening the friction. The sole-plate and cheek have to bear about one-half of the total weight or friction on the whole plough body, and if we substitute wheels for these we can diminish it greatly. For this purpose the wheels must be placed either in a line with the body of the tool, or else behind it, as exemplified by the "gang" or wheel ploughs in common use in America,—in which case the front wheels are sometimes dispensed with altogether. The friction at the axle of a wheel is, of course, very much less than that of the two large sliding surfaces.

Yoking Horses to a Plough.—In the yoking of the horses, again, certain mechanical principles come into play. The "centre of resistance" of the plough—that is, the point round which it would naturally balance itself when moving in work—is not a fixed point, but is about the heel of the share, and in the middle of the body. The horses really pull from this part; but as it is impossible to yoke them directly to it, the beam comes into use for this purpose, and the line of draught from the shoulder-hook of the haims to this point

must pass through the bridle of the beam, else the plough will not move properly at the depth required. Again, the plough moves forward in a horizontal direction, while the horses are pulling obliquely upwards. Some portion of their power is therefore wasted from this indirectness, while to counteract the tendency to go upward, the point of the share is turned down a little, or the plough is set with a tendency to go deeper of itself. The draught-chains should therefore be as long as possible, consistent with convenience of handling, while a foot or so of chain between the whipple-trees and bridle is a great help. Practice has ruled that a total of about 10 feet from shoulder-hook to bridle-pin is the best mean.

Weight of Ploughs.—Ploughs, of course, must not be too heavy; but, on the other hand, they might be too light, not only on account of the liability of the parts to be too weak, but also because a heavy article has more "inertia"—that is, power of its own weight or mass to resist little jerks or shocks from stones, &c. Practice in this case, again, has found that 15 to 20 stones are the handiest limits.

Advantages and Disadvantages of American Ploughs.—From these statements of elementary facts in mechanics, it will be seen that the short, dumpy, and light American ploughs are made contrary to the ordinarily accepted rules of proportion of parts. But on the lighter and easier worked soils this does not hinder them from being successfully used, more especially as their pulverising power is a desirable point in such cases. They do not work so easily on stiff clay, however, as it does not pulverise readily, but by using wheels and long handles they have been made very effective. The stilt being so short, wheels are a necessity in guiding, as the ploughman has little control over them, while the large angle of the breast increases the draught more than a long sloping one would do. Much of their superiority lies in the material of which they are made—the fine polish of the wearing surfaces reducing the draught to a great extent. If the ordinary style of plough were made of the same material as these, it would be much improved.

Draught of Ploughs.—There is a very great variation in the draught of different ploughs—that is, in the amount of power required by the horses to pull them through the soil. By means of a dynamometer this force can be measured in pounds or hundredweights, and of course, if everything else is right, the less exertion required by the horses the better. In the older forms of the plough—made mostly by country blacksmiths of malleable and cast iron, and still in very common use—the draught for a furrow 10 inches wide and 7 inches deep in medium soil is from 4 to 6 cwt. This is quite within the power of two good ordinary farm-horses, but it may be looked on as the limit, and no one who inquires into the matter will be satisfied nowadays with an implement requiring more power than this to work it.

From the introduction of improved forms of the wearing parts, and the use of chilled steel as a material, the resistance due to the tenacity of the soil and to friction has been so much reduced, that the same work can now be done with about half the expenditure of horse-power. We can therefore now plough much deeper with horses than it was possible to do at one time, and this is an additional reason in favour of deep work where the soil renders it desirable or beneficial.

Plough-staff.—A necessary accompaniment of every plough is the *plough-staff*, or plough-spade, fig. 301. It shovels off the mould that adheres to the breast of the mould-board, pushes away stubble or weeds which accumulate in the angle of the coulter and beam, and strikes out a stone when one fixes itself between the points of the coulter and sock. It lies upon the stilt, the spade being inserted into a staple in the bosom of the plough.

Swing-trees.—Horses are yoked to the plough by means of a set of levers named *swing-trees*, arranged so as to cause the united strength of the horses to be exerted at one point, by linking the ring of the swing-trees to the hook



Fig. 301.—
Plough-
staff.

of the bridle of the plough. Swing-trees are used for attaching any number of horses to other implements besides the plough, such as harrows, small ploughs, &c.

In the plough-yoke a set of swing-trees consist of 3, as in fig. 302. The swing-trees are arranged in the position in which they are employed in working. The section of the main swing-tree is at the centre of attachment, with clasp and

eye mounting, the scale of which is double the size of the principal figure in the cut.

Swing-trees are for the most part made of wood—oak or ash; sound English oak is by much the most durable—though good Scots ash is the strongest, so long as it remains sound, but it is liable, by long exposure, to a species of decay resembling dry-rot, and thereby becomes brittle. They are now also

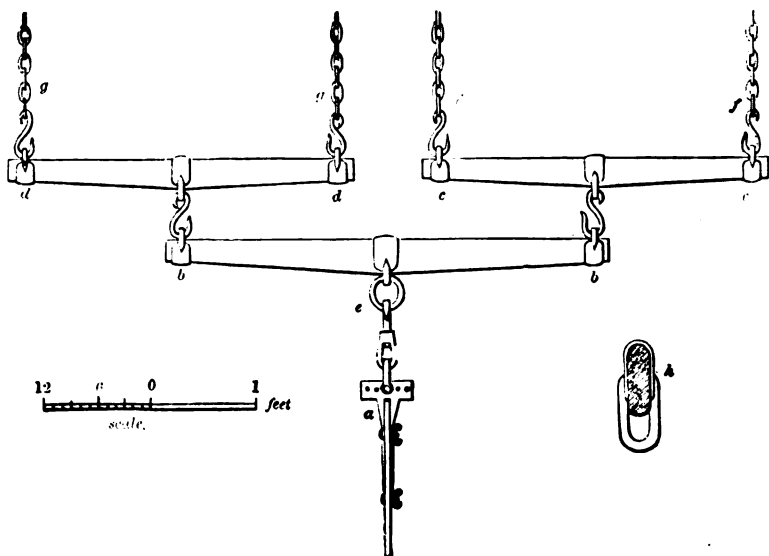


Fig. 302.—Swing-trees for two horses.

a Bridle of the plough.
b Main swing-tree.
e Ring of main swing-tree.

c c Furrow or off side swing-tree.
d d Land or near side swing-tree.

f g Trace-chains from the harness.
A Section of main swing-tree.

very often made of iron, and of various patterns, designed to give strength with lightness and durability.

Yoking 3 Horses to a Plough.—Ploughing is sometimes performed by three horses, as in cross-furrowing, or in breaking up stubble in autumn, when the land is clean, or in ploughing old rough lea ground. There are various ways of yoking three horses to the plough: the simplest is a pair working in the common swing-trees, fig. 302, with a light chain attached by a shackle to the middle of the main swing-tree. To this chain a third horse is yoked, taking his place in front of the other two, in unicorn fashion. This yoke is defective, inasmuch as there are no means

of equalising the draught of the third horse.

Perhaps the most perfect method of yoking a 3-horse team is abreast, with *compensation levers*, fig. 303—a statical combination, which is at once correct in its equalisation, scientific in principles, and elegant in arrangement. Between the main swing-tree and the three small ones the compensating apparatus is placed. Two of these are levers of the first order, but with unequal arms, the fulcrum being fixed at one-third of the entire length from the outward end of each; the arms of these levers are therefore in the proportion of 2 to 1, and the entire length of each between the points of attachment is 27 inches. The two

levers are hooked by means of their shackles to the main swing-tree; and the three small swing-trees are hooked to the compensation lever.

Saving a Weak Horse.—The considerate farmer will frequently see the

propriety of lightening the labour of some individual horse in this more than in the ordinary method of ploughing; and this is easily accomplished by the compensation apparatus. For this purpose, one or more holes are perforated in

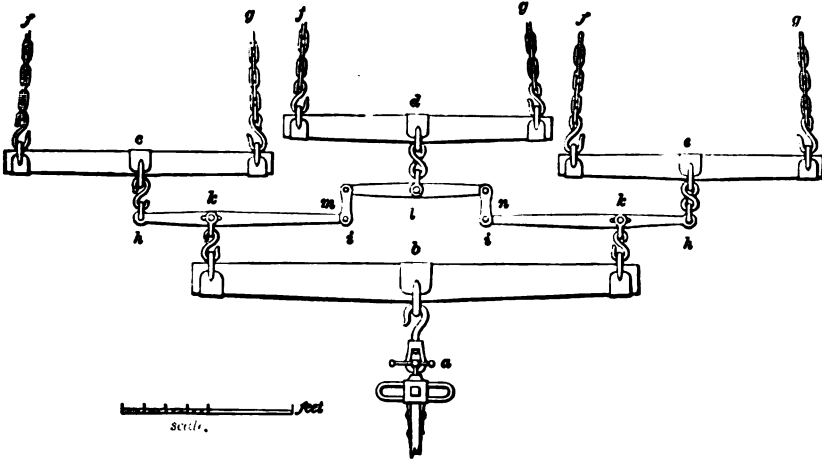


Fig. 303.—*Swing-trees for three horses.*

a Bridle of the plough.
b Main swing-tree.

c d e Common swing-trees for a horse each.
f g Trace-chains from harness.

h i k l m n Compensating apparatus of three levers of iron.

the levers *h i*, on each side of the true fulcrum *k*, to receive the bolt of the small shackle *k*. By shifting the shackle and bolt, the relation of the forces *h* and *i* are changed, and that in any proportion that may be desired; but it is neces-

sary to observe that the *distance* of the additional holes on either side of the central hole or fulcrum of equilibrium in the system, should be in the same proportion as the length of the arms in which the holes are perforated. Thus,

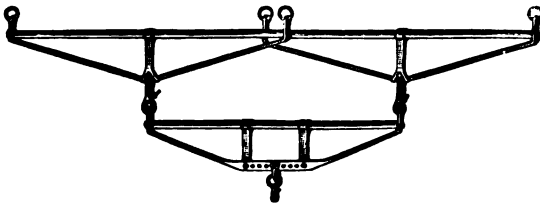


Fig. 304.—*Trussed iron whipple-trees.*

if the distance between those in the short arm is half an inch, those in the longer arm should be an inch. By such arrangement, every increase to the exertion of the power, whether on the long or the short arm, would be equal.

Fig. 304 represents a set of trussed tubular iron whipple-trees made by Kells, Meata, & Co., Gloucester. They

combine lightness, strength, and durability, and are adapted for two and four horses. By shifting the hook on the balance-bar, these whipple-trees can be used at the plough, with two horses in the furrow and one on the land, or with a colt or weak horse beside a strong one.

Yoking 4 Horses.—*In the yoking of*

4 horses, the best method is as in fig. 305. In this arrangement the balance of forces is perfectly preserved; for the hind horses and the leaders, as they pull at opposing ends of the chain, 11 feet in length, passing round a pulley, which must inevitably be always in equilibrium, each

pair of horses has an equal share of the draught; and from the principles of the common swing-trees through which each pair acts, the individual horses must have an equally perfect division of the labour. In order to prevent either the hind horses or the leaders from slipping

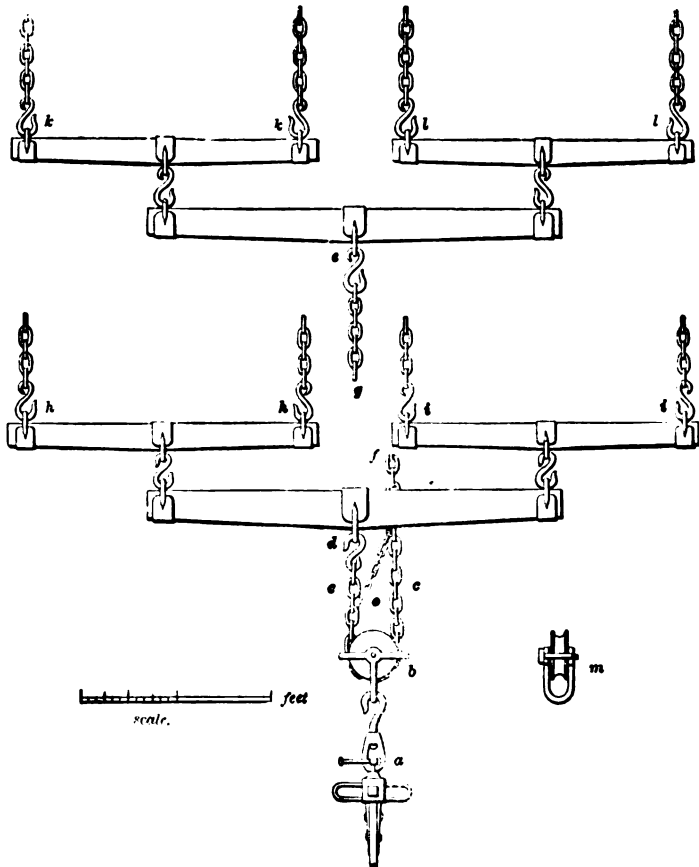


Fig. 305.—*Swing-trees for four horses.*

a Bridle of the plough.

b Pulley of cast-iron.

m Edge-section of pulley.

c Link-chain wove round the pulley.

d A set of common swing-trees.

e Another set of common swing-trees.

g f Chain connecting the two sets of swing-trees through the pulley.

h i k l Trace-chains from the harness.

o Check-chain.

too much ahead, it is common to apply a light check-chain of about 15 inches long, connecting the two parts of the main chain, so as to allow only a short oscillation round the pulley, which is limited by the check-chain. When this is adopted, care should be taken never to allow the check-chain to remain upon the stretch; for if it do so, the advan-

tage of equalisation in the yoke is lost, and it becomes no better than the simple foot-chain. In all cases of using a chain, that part of it which passes forward between the hind horses must be borne up by straps or cord attached to their back-bands, or suspended from their collars.

When more than four horses are yoked together, their strength is with difficulty

simultaneously applied. It is therefore much better to work 2 sets of 4 horses than 1 set of 8.

Harness.—Besides swing-trees, horses require *harness* to enable them to apply their strength to the plough. The harness, as used in Scotland, is simple and efficient.

Collar.—A form of collar long used in Scotland is shown in fig. 306. The collar surrounds the neck of the horse, and serves as a padding to protect the skin of the neck and the points of the shoulder, while the horse exerts his strength in the draught. The covering of this collar consists of leather stiffened in its upper part with stripes of whale-bone to form the cape. The body of the collar is stuffed with wheat-straw, or, what is better, rye-straw, and covered with strong twilled woollen cloth.

It will be observed that the under part of the collar is wider than the upper, because the under part of the neck of a horse is thicker than the upper or mane, upon which the collar rests; but as the crown of the head of the horse is broader than the muzzle, the collar is slipped over the head in the inverted position, and turned round upon the neck.

Fig. 307 shows a form of cape common in England. In modern English collars the cape is frequently made of a separate flap of leather, so that it can be folded down for the purpose of protecting the withers of the horse in wet weather. Similar capes are now often seen in Scotland, and are in both countries occasionally seen ornamented with flaring red worsted fringes round the edge, or with large tassels from the corner and middle, and even with bells.

Haims.—The *haims* are placed immediately behind the outer rim of the collar at *a*, fig. 306. They consist of two pieces fixed below the throat of the

horse with hooks and a link, and at the upper part at *a* with a leather strap. The pieces are formed entirely of iron, or of wood covered with thin sheet-iron, or of wood alone—now most frequently of iron. On each piece above the point of the shoulder of the horse is attached

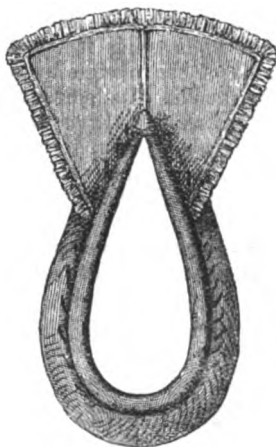


Fig. 307.—English draught-horse collar.

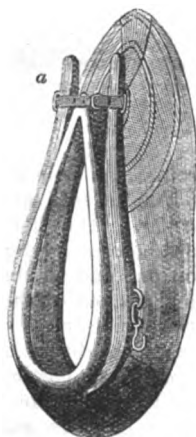


Fig. 306.
Scottish draught-horse
collar and haims.

a staple with a hook, to which is fastened the trace-chains of the plough, or the draught-chains of the cart. In some parts of the country the haims are never removed from the collar; in most parts they are taken off every time the horse is unharnessed.

Bridle.—A part of the harness is the *bridle*, which serves to guide the horse's head. It is commonly of simple form, consisting of a head-stall, nose-band, blinders, bit, throat-lash, and bearing-reins. In some parts of the country the blinders are omitted. The plea for the use of blinders is, that they prevent the horse looking around and being frightened by distant objects he cannot distinctly see, and they keep his attention steady to his work. But it is found that horses accustomed to look around them are seldom frightened, whereas those used to blinders are easily scared when these are taken off, or when they hear any uncommon noise. The want of them keeps the head cooler in summer, and saves the eyes from injury by lateral pressure.

Bearing-reins.—In draught-horses, *bearing-reins* may be dispensed with, as

unless the reins are allowed to hang loose, the animal has its head tied up, and cannot so easily lean forward to put its full power to the draught.

Back-band.—A piece of harness of the plough-gear is the *back-band*, which consists of a broad piece of leather passing over the horse's back, having small pads where it rests on the top of the back, both ends being fastened to the trace-chains of the plough by means of small iron hooks. Its office is to support the chains just *below* the line of draught; if above, the draught would become a strain upon the groins of the horse, through the medium of the back-band.

Plough-reins.—A necessary portion of the equipment of a draught-horse in harness is the *plough-reins*, which are made of cord, on purpose light and

strong, being fabricated of the best hemp. In some parts of the country, in the midland and northern districts, one rein is attached to the nigh horse in driving a pair in the plough, most of the horse's motions being performed by the command of the voice of the ploughman,—the only use of the rein being to pull the horses to the nigh side. To give the ploughman a perfect command of his horses, double reins should be used,—one passing from the left-hand stilt of the plough by the nigh side of the nigh horse, through one ring on the nigh side of the back-band, then through another ring on the nigh side of the haims, to the ring of the bridle-bit, to which it is fastened; the other rein goes from the right-hand stilt of the plough by the off side of the off horse, through rings in the back-band and haims to

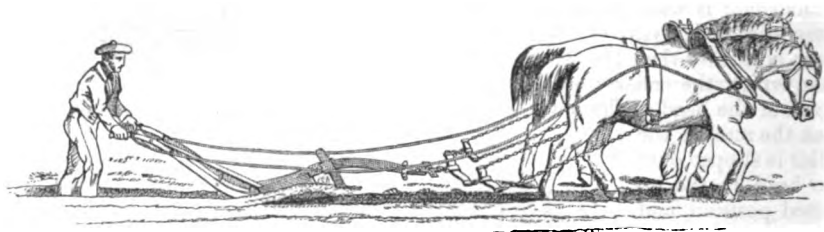


Fig. 308.—*Scottish plough at work with two horses.*

the bridle-bit on the off side. The other ends of the reins are usually held in the hands of the ploughman, or looped upon the handles of the stilts of the plough.

Weight and Cost of Harness.—The total weight of plough-harness may vary from 30 to 40 lb., and the cost from £2, 5s. to £3. Thus harnessed for the plough, each horse has not much weight to bear; nor is its harness costly, though made of the strongest harness-leather.

Some styles of English harness are much heavier, and also more costly. The harness required for a pair of horses for *carts* are 2 collars, 2 bridles, 2 haims, 2 saddles with breeching, and 2 belly-bands, costing in all from £9 to £12.

Ploughing with 2 Horses.—On examining the particulars of ploughing with two horses, fig. 308, the *collars* are

round the horses' necks; the top of the *haims* is seen at the upper part of the collar. The horses are yoked to the swing-trees by light *trace-chains*, linked on one end to the hooks of the haims, and hooked at the other into the eyes of the swing-trees. *Back-bands* of leather cross the back, near the groins of the horses, supporting the trace-chains by means of simple hooks. The *bridles* have blinders, and the *bearing-reins* are supported on the top of the haims. The *swing-trees* are hooked to the draught-swivel of the bridle of the plough; and being yoked abreast, the horses are enabled to exert their united strength much more effectually than if yoked one before the other. The two horses are kept together by a *leather strap*, buckled at each end to the bridle-ring, which prevents the horses separating beyond its length. The *reins* proceed from the ploughman's hands to the horses' heads.

The off-side horse—that is, the one nearest to the spectator in the figure—is walking in the *last-made* open furrow, the nigh horse walking on the *firm land*. The plough is in the act of turning over a furrow-*slice* of land, and the ploughman is walking in the *new-made* open furrow, leaning forward slightly upon the stilts to steady himself and the plough at the same time.

Ploughing with 3 Horses.—Fig. 309 shows the Scottish swing-plough at work with three horses. The yoking of the three horses through the instrumentality of the apparatus described in fig. 303 will at once be understood. The off horse—that is, next the spectator in the figure—is walking in the last-made furrow, the other two horses are on the firm land, while the ploughman is stepping in the new-made furrow. The depth

of the furrow in this case is 10 to 12 inches, instead of 7 or 8 inches—the usual depth of ploughing. The three horses plough to this depth in ordinary soils with great ease. The advantages of this method of ploughing are, that it uproots every tap-rooted weed; that the furrows being open to the influences of the elements in winter, the soil becomes so completely pulverised by the spring that any further ploughing then is unnecessary; that a simple grubbing renders the soil fit to be done up for potatoes or turnips; that much labour is thus saved in the busy season of spring, and the additional depth of soil stirred gives more room for bulky manures to be effectually covered, and greater scope for the roots of the cultivated plants to ramify in search of mineral food. These advantages from ploughing to this depth

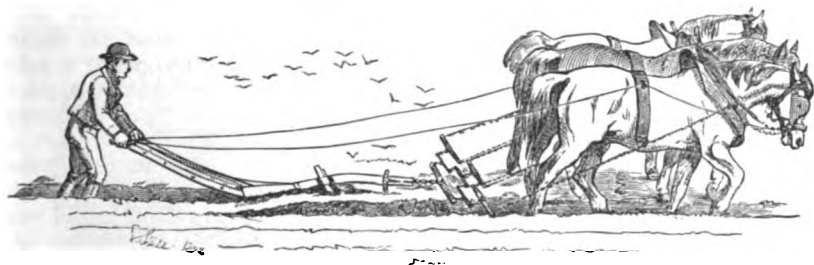


Fig. 309.—Scottish plough at work with three horses.

are, of course, derived only where the soil is deep, and the subsoil of a suitable character. In all respects this mode of ploughing is similarly conducted to that with two horses, as plainly indicated in the two figures.

Language to Horses.—Besides the use of reins, it is customary to desire horses to go through their motions, when yoked to the draught, with the voice, using the *language to horses*. It would be quite possible to cause horses to perform all their motions by means of the double reins alone, but the voice keeps up an understanding between the men and horses. It is not practicable to make horses at the plough go through the requisite movements with a single rein, unassisted by the voice; but too much use of the voice makes horses become regardless of it.

The language addressed to horses

varies in the different parts of the kingdom. The motions required of them at work are to go forward—to step backward—to go to the right from you—to come to the left towards you—to turn round—and to stop. The word *Wo* is universally used to stop and the word *gee* to go forward.

In all cases the speaker is supposed to be on the *near side* of the horse—its left side. The word *hup* is often used to go from, and *hie*, to come to, when describing any piece of work in which horses are employed.

ACTIONS OF VARIOUS PLOUGHS IN USE.

Small's Plough.—It would be well to make a comparison between the actions of the various ploughs in use before entering on the different methods of ploughing land; and first, of ploughs

designed on the principles laid down by Small, fig. 310:—

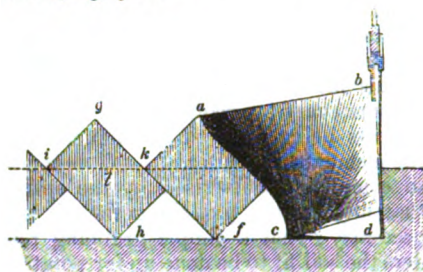


Fig. 310.—Effects of a rectangular furrow-slice.

- a b c d* Transverse section of mould-board.
- f, g h* Sections of furrow-slice.
- g k a* Right angle.
- i g k* Triangle equal to breadth of furrow-slice.
- i g, g k* Equal sides of triangle.
- g l* Half the breadth of furrow-slice.
- h f c d* Level sole of furrow.

In this example, the rectangular furrow-slice is 10 inches broad by 7 inches deep.

Wilkie's Plough.—Next of Wilkie's pattern, fig. 311:—

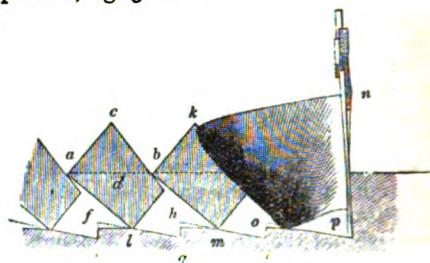


Fig. 311.—Effects of a crested furrow-slice.

- k n p o* Transverse section of mould-board.
- k m, e l* Sections of furrow-slice.
- c* Angle 84° or 75° .
- a c b* Isosceles triangle.
- a c* $6\frac{1}{2}$ inches, upper end of furrow-slice.
- l h* $4\frac{1}{2}$ inches, lower end of furrow-slice.
- f h o p* Crested furrow-sole.
- e f g, g h i* Triangular spaces $1\frac{1}{2}$ inch left unploughed.

In comparing the furrow-soles in figs. 310 and 311, besides the loss of time and

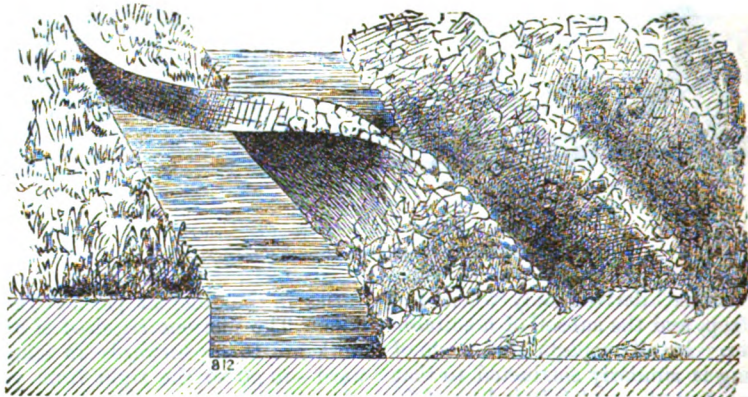


Fig. 312.—Wide and broken furrow by chilled plough.

labour in ploughing a breadth of furrow $8\frac{1}{2}$ inches, compared with a 10-inch furrow, the crested furrow-sole leaves part of the ground unploughed. Thus, in ploughing an imperial acre with a 10-inch furrow—leaving out of view the taking up of closings, turnings, &c.—the distance walked over by the man and horses will amount to 9.9 miles; with a 9-inch furrow the distance will be 11 miles; with an $8\frac{1}{2}$ -inch furrow, it will be $11\frac{1}{2}$ miles; and with a $7\frac{1}{2}$ -inch furrow, $13\frac{1}{4}$ miles.

Chilled-steel Plough.—The modern chilled-steel plough which does "digging"

work, cuts a furrow-slice which is quite different from either of the above. It is wide in proportion to its depth—14 inches wide and 5 inches deep being quite a common size,—but the main point about it is that from the action of the short concave wide-set mould-board the slice is crumpled up and turned over in a broken and pulverised condition, almost completely inverted, and the surface of the field left in a friable condition just ready for drilling in seed, or for leaving for the action of winter frost (fig. 312). It "cultivates" as well as ploughs.

Steam-ploughs and Diggers.—There are several forms of steam-ploughs, and these will be noticed in a subsequent chapter dealing with the application of steam-power to farm-work. This also applies to other tillage implements worked by steam.

PLOUGHING AND PLOUGHING-MATCHES.

Tempering the Plough.—The plough, as now made, consists of a number of parts; but how well soever those different parts may be put together, if not *tempered*, or adjusted—if any part has more to do than its own share of the work—the entire implement will move unsteadily. It is easy to ascertain whether or not a plough goes steadily, and is so by the following means:—

Less "Earth" required.—On holding a plough by the handles with both hands, while the horses are drawing it through the land, if it have a constant tendency to go deeper into the soil than the depth of the furrow-slice previously determined on, it is not going steadily. The remedy is twofold—either to press harder upon the stilts with the hands, and, by their power as levers, bring the share nearer the surface of the ground; or to put the draught-bolt of the bridle a little nearer the ground, and thus give the plough less "*earth*." The pressure upon the stilts should first be tried, as being the most ready at command; but should it fail of effecting the purpose, and the pressure prove too severe upon the arms of the ploughman, the draught-bolt should be lowered; and should both these expedients fail, there must be some error in another part of the plough. On examining the share, its point may possibly be found to dip too much below the base-line (fig. 288), which will cause it to go deeper than it should. This error in the share can be rectified only at the smithy.

More "Earth" required.—Again, the plough may have a tendency to come out of the ground. This cannot be remedied by supporting the stilts upwards with the arms, because the body of the ploughman having no support, he could not walk steadily in the furrow. Hence, a very short man can scarcely hold a plough steady at any

time, and does not make a desirable ploughman. The draught-bolt should, in the first instance, be placed farther from the ground, and give the plough more "*earth*." Should this not effect the purpose, the point of the share will probably be above the base-line, and must therefore be brought down to its proper level by the smith. The introduction of shares with movable point has been found advantageous in this as well as in other respects (fig. 293).

More "Land."—It may be difficult to make the plough turn over a furrow-slice of the desired breadth. This tendency is obviated by moving the draught-bolt a little to the right, which gives the plough more "*land*"; but in case it arises from some casual obstruction underground, such as direct collision against a small stone or a piece of unusually hard earth, it may be overcome by leaning the plough a little over to the right or left for the time.

Less "Land."—The tendency, however, may incline to take a slice broader than is wanted; in which case, for permanent work, the draught-bolt should be put a little to the left, which gives the plough less "*land*"; and for a temporary purpose the plough may be leaned over a little to the left.

These are the ordinary causes of unsteadiness in the *going* of ploughs; and though narrated singly, any two of them may combine to produce the same result, as the going deeper, or shallower, with cutting a too narrow or too broad furrow-slice. The most obvious remedy should first be tried; but both may be tried at the same time if a compound error is apprehended.

Hold the Plough level.—Some ploughmen habitually make the plough lean a little over to the left, giving it less land than it would naturally have, and to counteract the consequent tendency to a narrow furrow-slice, move the draught-bolt a little to the right. The ploughing with a lean to the *left* is a bad custom, because it cuts the lowest side of the furrow-slice with a slope, which gives the horses a lighter draught than when turning over a square furrow-slice. Old ploughmen, feeling infirm, are apt to practise this deceptive mode of ploughing. The plough should

always be level upon its sole, and turn over a rectangular furrow-slice.

Tall men, in having to stoop constantly, lean hard upon the stilts; and as this has the tendency to lift the plough up, they are obliged to put the draught-bolt higher to keep it in the ground.

A good ploughman will use none of these expedients, for he will *temper the irons*, so as there shall be no tendency in the plough to go too deep or too shallow into the ground, or make too wide or too narrow a furrow-slice, or cause less or more draught to the horses, or less or more trouble to himself, than the work requires to be performed in the best manner.

Tempering the "Irons."—In the attempt to temper irons, many ploughmen place the coulter in a position which increases the draught of the plough. When its point is brought down as far as that of the share, and projecting much to the left or land side, a stone in light land is very apt to be caught between the points of the coulter and share, which will have the effect of throwing the plough out of the ground. Such an accident is of little consequence in ploughing land to be ploughed again; but it disfigures the land in ploughing lea, and must be rectified instantly: in doing this, however, time is lost in backing the horses to the spot where the plough was thrown out. To avoid such an accident on lea-ploughing, in *stony land*, the point of the coulter should be put immediately above, and almost close upon, that of the share, when they will both cut the soil clean. In smooth soils, free of small stones, the relative positions of the points of the coulter and share have not the same influence upon the steadiness of the plough.

Plough-"irons."—The state of the irons themselves has a material effect on the temper of the plough. If the cutting edge of the coulter, and the point and cutting edge of the share, are steeled, the irons will cut clean, and go long in smooth soil. This is an economical treatment of plough-irons for clay soils. But in gravelly and all sharp soils the irons wear down so very fast, that farmers prefer them made of ordinary iron, and have them laid anew fre-

quently, rather than incur the expense of steeling, which perhaps would not endure work much longer in such soils. Irons are now seldom if ever steeled; but whether steeled or not, they are always in the best state when sharp and of the requisite dimensions. In English smooth soils, cast-iron shares are often used. In Scotland the soil is commonly too stony for cast-iron to stand the work, but could cast-iron shares be procured very cheap, they might be as economical as malleable-iron shares. The best material now used for the wearing parts of ploughs is chilled steel, which, on account of its extreme hardness, resists wear for a long time, while the fine surface it takes on lessens the friction to be overcome by the horses.

Keep the Plough in good Order.—An imperfect state of the mould-board is another interruption to the tempering of a plough. When new and rough, the soil adheres to it, and if pressing heavily against the turning furrow-slice, causes the plough to deviate from its right course. On the other hand, when the mould-board is worn away much below, it leaves too much of the crumbled soil on the bottom of the furrow, especially in loose soils. Broken side-plates easily admit the soil through them into the body of the plough, and cause a rough and unequal face on the firm land side; and when soil accumulates in the body, it affects the plough both in temper and draught. These remarks on tempering are made on the supposition that ploughs are well made, and may therefore be tempered equally well; but ploughs are sometimes so ill constructed, that the best tempering the irons are capable of receiving will never make them do good work. It is more economical to have a good new plough than to work for a length of time with a worn-out one.

Good Ploughmanship.—When all the particulars which ploughmen should attend to in executing their work—in having their plough-irons in a proper state of repair, in tempering them according to the kind of ploughing to be executed, in guiding their horses, and in ploughing the land in a methodical way—are considered, it ceases to surprise one that so few ploughmen be-

come first-rate workmen. Good *ploughmanship* requires greater faculty of observation than most people would readily imagine—greater than many young ploughmen possess,—greater judgment than most will take time to exercise,—more patience than most will bestow to become familiarised with every particular,—and greater skill than most can acquire. To be so accomplished, implies the possession of high talent for workmanship.

Learning Ploughing.—Ploughmen cannot learn their art at a very early age, and every business ought to be taught then to reach a high attainment in it. Ploughing requires a considerable degree of strength even from grown-up men, and it bears much harder on the learner; but even after young men have acquired sufficient strength to hold the plough, they are left to learn ploughing more through sheer experience than by tuition from those better acquainted with the art. Experience cannot be transmitted from father to son more in this than in any other art; and in this, as in other arts, improvement is more frequently effected by imitation than by efforts of individual ingenuity and study.

The best Ploughmen and Stewards.

—The best ploughmen are generally those who have been taught directly by their fathers, and work constantly upon their fathers' farms; and they make, besides, the best stewards, because they have been accustomed to command servants, and have not associated freely with them. A steward promoted from the rank of a common ploughman is apt—unless he is a man of exceptional strength and firmness of character—to continue on too familiar a footing with them to sustain the authority due to his situation, and on being aroused to enforce authority perhaps becomes tyrannical.

Boy Ploughmen.—In England, boys are frequently employed to *tend* the plough, for they cannot be said to hold it, as it is so constructed with wheels and apparatus as to turn over the soil without the aid of man, and his aid is required only for the turnings at the ends of the ridges.

Weight of Deep and Shallow Fur-

rows.—It may be worth while to show the great difference in the weight of soil turned over in a deep and shallow furrow. If 10 inches are taken as a fair width for a furrow-slice, there will be 18 such slices across a ridge of 15 feet in breadth; and taking 7 inches as a common depth for such a furrow-slice, a cross section of the slice will have 70 square inches. A cubic foot of earth is thus turned over in every 24.7 inches of length of such a slice; and taking 1.48 as the specific gravity of common earth, the 24.7 inches of slice will weigh 6 stones 8 lb. imperial. If a furrow of only 4 inches in depth is taken, with its breadth only of 9 inches, the area of the slice will be 36 square inches, and its weight will be 3 stones 5 lb., a considerable difference of weight for horses to turn over in the same distance travelled. With the furrow of the 3 or 4 horse plough, say 14 inches by 10 inches, the weight of soil turned over would be 13 stones 2 lb.

Form and Position of Furrow-slice.

—The proper form and position of the furrow-slice are requisites in good ploughing. The furrow-slice should be of such dimension, and laid in such position, that the two exposed faces in a series of slices shall be of equal breadth, and any departure from this rule is a positive fault. Laid up agreeably to this rule, furrow-slices will not only present the maximum of surface to the atmosphere, but also contain the maximum of cubical contents.

Fig. 313 represents the movement of the furrow-slice, as well as its position after it is laid by the plough. An examination of this figure also shows that the extension of the slice only takes place along the land-side edge, from *e* to where the backward flexure is given to it when rising on the mould-board at *d'*; and where it is again compressed into its original length, in being laid down by the back part of the mould-board at *c*. The slices are laid over at an angle of 45 degrees; and in slices of 7 inches in depth and 10 inches in breadth, the altitude of the triangle is 5 inches, each side 7.071 inches, and the sum of the two exposed faces 14.142 inches.

These figures apply only to the rectangular furrow-slices by the common ploughs made after Small's type. Those of ploughs made on a different pattern will differ in the angle of the slice, and in the dimensions of the triangular crest.

Characteristics of correct Ploughing.—Correct ploughing possesses these characteristics: The furrow-slices should be quite straight; for a ploughman that cannot hold a straight furrow is unworthy of the name. They should be quite parallel as well as straight, which shows that they are of a uniform thickness; for thick and thin slices lying upon one another present irregularly

parallel and horizontal lines. They should be of the same height, which shows that they have been cut of the same breadth; for slices of different breadths, laid together at whatever angle, present unequal vertical lines. They should present to the eye a similar form of crest and equal surface; because, where one furrow-slice exhibits a narrower surface than it should have, it has been covered with a broader slice than it should be; and where it displays a broader surface than it should have, it is so exposed by a narrower slice than should be. They should have their back and face parallel; and to discover this property after the land

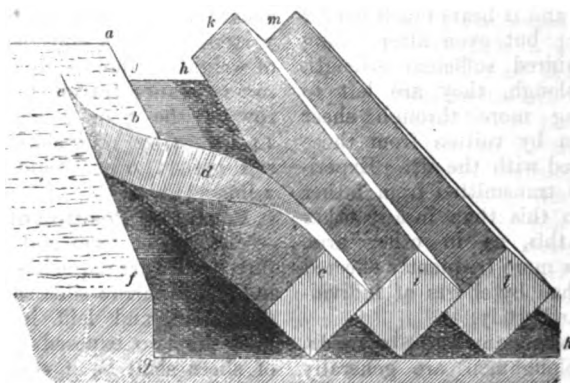


Fig. 313.—View of the movement of the furrow-slice.

a b Edge of land cut by preceding furrow.
c d Slice being turned over by the plough.
e f Edge of land being left by the ploughing furrow.

i k, l m Furrow-slices previously laid over.
g A Level sole of furrow.

has been ploughed requires minute examination. They should lie easily upon each other, not pressed hard together.

The ground, on being ploughed, should feel equally firm under the foot at all places, for slices in a more upright position than they should be not only feel hard and unsteady, but will allow the seed-corn to fall between them and become buried. When too flat, they yield considerably to the pressure of the foot; and they cover each other too much, affording insufficient mould for the seed. They should lie over at the same angle, presenting crests in the best possible position for the action of the harrows. Crowns of ridges formed by the meeting of opposite furrow-slices should neither be elevated nor depressed

with regard to the rest of the furrows in the ridge; although ploughmen often commit the error of raising the crowns too high into a crest, the fault being easily committed by not giving the first furrow-slices sufficient room to meet, and thereby pressing them against each other.

The last furrow-slice should be uniform with those of the rest of the ridge; but ploughmen are very apt to miscalculate the width of the slices near the edges of the ridges; for if the specific number of furrow-slices into which the whole ridge should be ploughed are too narrow, the last slices of the open furrow will be too broad, and will therefore lie over too flat; and should this too broad space be divided into two furrows, each

slice will be too narrow, and stand too upright. When the last furrows are ill made, the open furrow cannot be proportionately ploughed out; because, if the space between the last furrows is too wide, the open furrow must be made too deep to fill up all the space; and if too narrow, there is not sufficient mould to make the open furrow of the proper size. If the last furrow-slices are laid too flat, the open furrow will throw too much mould upon the edges next the open furrow, and make them too high. When the last furrows of adjoining ridges are not ploughed alike, one side of the open furrow will have less mould than the other. From a consideration of these particulars, it is obvious that ploughing land correctly, which is best exhibited in lea-ploughing, is an art which requires a skilled hand and correct eye, both of which are much interfered with in the management of the horses. Hence a ploughman who has not his horses under strict command cannot be a good hand.

Speed of Horses Ploughing.—The usual speed of horses at the plough may be ascertained in this way: A ridge of 5 yards in breadth requires a length of 968 yards to contain an imperial acre; to plough which at 9 bouts (a *bout* being a walk along a ridge and back), with a 10-inch breadth of furrow-slice, counting no stoppages, will make the horses walk 9.9 miles, which in 10 hours gives a speed of 1742 yards per hour; at 10 bouts of 9-inch furrow breadth, gives 11 miles of travel to the horses, or 1936 yards per hour; and at $7\frac{1}{2}$ bouts of 12-inch furrow-breadth, gives $6\frac{1}{3}$ miles of travel to the horses, or 1452 yards per hour. But as ridges of 968 yards in length are very rare, and as horses cannot draw a plough that distance without being affected in their wind, and as allowance must be made for time lost in turning at the ends of ridges, as well as affording rest to horses, those speeds will have to be considerably increased to do that quantity of work in the time.

In ploughing an acre on ridges of 270 yards in length, which is about the length of ridge considered best for horses in draught, the time lost by turnings, in ploughing 10 hours, with

a 10-inch furrow-slice, is 1 hour 22 minutes. However easy the length of ridge may be for the draught, horses cannot go on walking in the plough for 5 hours together (a yoking) without taking breaths. Now 270 yards of length of ridge give 3.6 ridges to the acre, or 32 bouts of 10-inch furrows; and allowing a rest of 1 minute in every other bout, 16 minutes will have to be added to the 1 hour 22 minutes lost—that is, 1 hour 38 minutes lost out of every 10 hours, for turnings and rest. Thus 17,496 yards will be ploughed in $8\frac{1}{3}$ hours, or at the rate of rather more than 1 and $\frac{1}{5}$ mile per hour, or $11\frac{1}{3}$ miles of walking in ploughing an acre in $8\frac{1}{3}$ hours. These results are perhaps near the truth in ploughing lea in spring; they are too little in ploughing bare land in summer, and perhaps too much in ploughing heavy stubble-land in winter; but as lea-ploughing is the standard by which all others are estimated, the results arrived at may be taken as an approximation to the truth.

Hence this table:—

Length of ridge.	Breadth of furrow-slice.	Time lost in turning.	Time devoted to ploughing.	Hours of work.
Yards.	Inches.	H. M.	H. M.	H.
78	10	5 11	4 49	10
149	...	2 44	7 16	...
200	...	2 1	7 59	...
212	...	1 56½	8 3½	...
274	...	1 22	8 32	...
270	12	1 8	8 52	...

Long and Short Ridges.—Thus it appears that a ridge of no more than 78 yards in length requires 5 hours 11 minutes out of every 10 hours for turnings at the landings, with a 10-inch furrow-slice; whereas a ridge of 274 yards in length only requires 1 hour 22 minutes for turnings—making a difference of 3 hours 49 minutes in favour of the long ridge as regards the saving of time.

Very short *butts* in a field, therefore, involve much loss of time with the plough, the harrow, and the sowing-machine.

Extent of Land ploughed at different Speeds.—Further data from sim-

ilar experiments are the quantities of land ploughed at different speeds at given breadths of furrow-slices, thus:—

Speed. Rate per Hour.	Breadths of furrows ploughed.	Distance walked in 8½ hours.		Quantity of land ploughed in 8½ hours at that speed.		
Yards.	Inches.	Miles.	Yards.	A.	R.	P.
1452 Miles.	12	6	520	1	0	0
1	9	8	1284	0	3	1
	10	8	440	0	3	14
1½	9	12	642	1	0	21
	10	12	220	1	0	34
2	9	17	808	1	2	2
	10	16	880	1	2	28

A Regular Pace best.—Horses driven in the plough beyond their ordinary step cannot draw equally together, and the plough is consequently held unsteadily, having a tendency to take too much land; to obviate which, the ploughman leans the plough over to the left, when it raises a thin broad furrow-slice and lays it over at too low an angle. On the other hand, when the horses move at too slow a pace, the ploughman is apt to forget what he is about, and the furrow-slices will then, most probably, be made too narrow and too shallow; and although they may be laid over at the proper angle, and the work seem well enough executed, there will be a deficiency of mould in the ploughed soil. A regular pace is therefore the best for man, horses, and work.

Ploughing Steep Land.—The steepness of the ground is a circumstance which greatly affects the speed of horses at work on hilly farms; and it is not unusual to find the ridges traversing such steeps straight up and down. Ridges in such a position are laborious to plough, to cart upon, to manure, and for every operation connected with farming. The water runs down the furrows when the land is under the plough, and carries to the bottom of the declivity the finest portion of the soil. In such a position, a ridge of 270 yards is much too long to plough without a breathing to the horses. Although the general rule for making ridges to run N. and S. is the correct one, in such a situation as a steep acclivity they should

slope across the face of the hill; and the slope will not only be easier to labour, but the soil prevented being washed away in the furrows. But the direction of the slope should not be made at random,—it should so decline as that the plough shall lay the furrow-slice down the hill when in the act of climbing the incline; and on coming down, the horses will be better able to lay the furrow-slice up against the inclination of the ground. What the length of the ridges on such a slope ought to be cannot be easily determined, but about 150 yards would be enough for the horses to draw at one breathing. It will be better for labouring an arable farm to have 2 fields each 150 yards long, one higher up the slope than the other, than have the whole ground in one field of 300 yards in length.

Ploughing-matches.—Although differences of opinion exist as to the usefulness of ploughing-matches, it can hardly be doubted that since their institution the skill of our ploughmen has risen considerably: not but that individual ploughmen could have been found before as dexterous as any of the present day. This improvement is not to be ascribed to the institution of ploughing-matches alone, for, no doubt, superior construction of implements, a better kept, better matched, superior race of horses, and superior judgment and taste in field labour in the farmer himself, have been potent elements in influencing the handicraft of ploughmen.

Highland and Agricultural Society Medals for Ploughing.—Since early in the nineteenth century the Highland and Agricultural Society of Scotland has regularly offered a large number of medals to be awarded for the best ploughing at competitions held throughout Scotland. Over 200 of these medals are usually given every year, and the rivalry and interest they create amongst ploughmen have done much good.

How Ploughing-matches are Conducted.—Ploughing-matches are generally very fairly conducted in Scotland. They usually take place on lea ground, the ploughing of which is considered the best test of a ploughman's skill, though drilling is perhaps quite as difficult of correct execution. The best part

of the field is selected for the purpose, and the same extent of ground is allotted to each competitor. A peg, bearing a number, is fixed in the ground at the end of each lot, which are as many as ploughs entered in competition. Numbers, on slips of paper corresponding to those on the pegs, are drawn by the competing ploughmen, who take the lots as drawn. Ample time is allowed to finish the ploughing of each lot. Although quickness of time in executing the same extent of work is not to be compared to excellency of execution, it should enter as an element in deciding the question of skill; but this it seldom does at ploughing-matches. Each competitor is obliged to "feer" or "draw off" his own lot, assort and guide his own horses, and trim his plough-irons, without assistance.

Judges at Ploughing-matches.—The judges are brought from a distance, so that they can have no personal interest in the exhibition, and in some cases they have been requested to inspect the ground after all the ploughs have been removed, having been kept away from the scene during the time the ploughs were engaged. This appears to be an objectionable part of the arrangements, which is made on the plea that, were the judges to see the ploughs at work, some particular ones might be recognised by them as belonging to friends, and their minds might thereby be biassed in their favour. Such a plea is a poor compliment to the integrity of a judge, and should never be put forward.

The judges ought to be present all the time of the competition, when they could leisurely, calmly, and minutely ascertain the position and depth of the furrow-slices, and mature their thoughts on points which might modify first impressions. Inspection of the finished surface cannot furnish information whether the land has in all respects been correctly ploughed, which can only be obtained by comparing the soles of the furrows while the land is being ploughed. There is something also to be gained in observing the manner in which the ploughman guides his horses in making the best work in the shortest time.

Quantities of Earth turned over
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by different Ploughs. — Small's type of plough lays over a slice of a rectangular, and Wilkie's of a trapezoidal form, while making a high-crest slice and serrated furrow-sole, containing one-seventh less earth than the rectangular. Now when judges are prohibited seeing the work done in the course of execution, the serrated extent of the furrow-sole cannot so well be ascertained by removing portions of the ploughed ground here and there by the spade, as by constant inspection. As equal ploughing consists in turning over equal portions of soil in the same extent of ground, other things being equal, a comparison of the quantity of earth turned over by these two kinds of ploughs can only be made in this way: In a space of 1 square yard turned over by each, taking a furrow of 7 inches in depth, and the specific gravity of soil at 1.48, the weight of earth turned over by Small's type of plough would be 34 st. 9 lb., while Wilkie's would turn over only 29 st. 10 lb., making a difference of 4 st. 13 lb. in the small area of 1 square yard. With these results, is it fair to say that the horses yoked to Small's plough have done no more work than those yoked to Wilkie's? or that the crop for which the land has been ploughed will receive the same quantity of loosened mould to grow in in these cases, merely because the surface may please the eye more in the one case than in the other?

High-crested Furrows Objectionable.—The primary objects of ploughing-matches must have been to produce the best examples of ploughmanship—and by the best it must be understood that kind of ploughing which shall not only *seem* to be best done, but *has been* best done. The award should be given to the plough that produces not only a proper surface finish, but also turns over the greatest quantity of soil in the most approved manner. That this combination of qualities has ceased to be the criterion of merit, is now sufficiently apparent to any one who will examine for himself the ploughing which has been rewarded in ploughing-matches; and the cause of such awards is this:—

Wilkie's plough gave rise to the high-crested furrow-slice. It cannot be denied that the ploughs made on this principle

produce work on lea land highly satisfactory to the eye of any person who appreciates regularity of form; and as there are many minds which dwell with pleasure on beauty of form, but combine not that idea with usefulness, it is no wonder that work which thus pleases the eye, and satisfies the judgment through the sense of sight only, should become a favourite one. While the crested system of ploughing kept within bounds it was well enough, but in course of time the taste for the practice became excessive; and at length, losing sight of the useful, a depraved taste sacrificed utility to beauty, in as far as ploughing is concerned. This taste gradually spread itself over certain districts, and plough-makers vied with each other in producing ploughs that should excel in that particular quality. A keen spirit of emulation amongst ploughmen kept up the taste amongst their own class, and frequently the sons of farmers became successful competitors in the matches, which assisted to give the taste a higher tone.

Thus, by degrees, the taste for this mode of ploughing spread wider and wider, until in certain districts it became the prevailing method. At ploughing-matches in those districts, the criterion of good ploughing was generally taken from the appearance of the surface; furrow-slices possessing the highest degree of parallelism, exposing faces of unequal breadth, and, above all, a high crest, carried off the palm of victory. More than once have a quorum of ploughing judges been seen "plodding their weary way" for two hours together over a field, measuring the breadth of faces, and scanning the parallelism of slices, but apparently never considering the underground work of any importance in enabling them to decide correctly. Under such regulations it is not surprising that ploughmen devote their abilities to produce work to satisfy this vitiated taste, and that plough-makers find it their interest to encourage the desire, by exaggerating more and more the construction of those parts of the plough which produce such fine results. Thus have the valuable institutions of ploughing-matches, in the districts alluded to, been unwittingly made to engender an innovation which, though

beautiful enough,—and, when practised within due bounds, is also useful,—has induced a deterioration in really useful and sound ploughing.

A useful Appendage of a Plough.—Ploughs should always be provided with the useful appendage of an *iron hammer*, fig. 314. The hammer and handle are forged in one piece of mal-

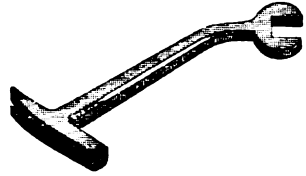


Fig. 314.—Iron hammer nut-key.

leable iron, the handle being formed into a nut-key. With this simple but useful tool the ploughman has always at hand the means by which he can, without loss of time, alter and adjust the position of his plough-irons—the coulter and share—and perform other little operations which circumstances or accident may require, for the performance of which most ploughmen are under the necessity of taking advantage of the first stone they can find, merely from the want of this simple instrument. The hammer is slung in a staple fixed in the side of the beam in any convenient position. This little tool is now sent out by almost all makers as a regular appendage of the plough.

Plough-slide.—In removing ploughs from one field to another, or along a hard road to a field, instead of sliding them upon their sole-shoe, which is difficult to do



Fig. 315.—Plough-slide.

when they have no hold of the ground, or upon the edge of the feather of the sock and the side of the mould-board—which is a more easy mode for the ploughman than the former, and is consequently more commonly taken—every ploughman should be provided with a plough-slide, a simple and not costly implement, as in fig. 315. It consists of a piece of hardwood board 3 feet 4 inches long, 8 inches broad, and 2 inches thick, in which a long staple *a*

is driven to take in the point of the sock; and at *b* are fastened two small bars of wood, longways, and at such distance from one another as to take between them the sole-shoe of the plough. On the under side of the board are nailed two pieces of flat bar-iron, to act as skeds to the slide. Upon this implement the plough may be conveyed with comparative ease along any road or headridge.

PLOUGHING DIFFERENT FORMS OF RIDGES.

One might imagine that, as the plough can do nothing else but lay over the furrow-slice, ploughing would not admit of any variety; but the student will soon see the *many forms in which land may be ploughed*.

Modes of Ploughing.—The several modes of ploughing have received characteristic appellations—such as gathering up; crown-and-furrow ploughing; casting or yoking or coupling ridges; casting ridges with gore-furrows; cleaving down ridges; cleaving down ridges with gore-furrows; ploughing two-out-and-two-in; ploughing in breaks; cross-furrowing; angle-ploughing, ribbing, and drilling.

Varying Methods to suit Soil and Season.—These various modes of ploughing have been contrived to suit the nature of the soil and the season of the year. Clay soil requires more caution in being ploughed than sandy or gravelly, because of its being more easily injured by rain; and, indeed, it is a bad thing to plough any land in a wet state. Greater caution is therefore required to plough all sorts of land in winter than in summer. The precautions consist in providing facilities for surface-water to flow away, and some sorts of ploughing afford greater facilities than others. Though the different seasons thus demand their respective kinds of ploughing, some modes are common to all seasons and soils. Attention to the various methods can alone enable the agricultural student to understand which kind is most suitable to the circumstances of the soil and the peculiar states of the season. To give the best idea of all the modes, from the simplest

to the most complicated, let the ground be supposed to be perfectly flat on the surface.

The Parts of Ridges.—The supposed flat ground, after being subjected to the operation of the plough, is left in *ridges*, each of which occupies spaces of similar breadth. Ridges are composed of various parts—furrow-slices laid upon and parallel to one another, by the going and returning of the plough from one end of the ridge to the other: the middle line of the ridge receives the name of the *crown*,—the two sides, the *flanks*,—the openings between the ridges, the *open furrows*,—the edges of the furrow-slices, next the open furrows, the *furrow-brows*; and the last furrows, which are small, to narrow the open furrows, are the *mould* or *hint-end furrows*.

Direction of Ridges.—Ridges are usually made to lie in the direction of N. and S., that the crop growing upon both their sides may receive the light and heat of the solar rays in an equal degree throughout the day; but they, nevertheless, are made to traverse the slope of the ground, whatever its aspect may be, with the view of allowing rain-water to flow most easily away, without damaging the surface of the ground.

Width of Ridges.—Ridges are formed of different breadths, of 10, 12, 15, 16, and 18 feet, in different parts of Scotland, and in England they usually vary from 7 to 14 feet. These various breadths are occasioned partly by the nature of the soil, and partly by local custom. As regards the soil, clay soil is formed into narrow ridges, to allow the rain to flow off very quickly into the open furrows, and in many parts of England is ridged at only 14 feet in width, and in some localities is reduced to ridglets of $3\frac{1}{2}$ or 7 feet. In Scotland, even on the strongest land, ridges are seldom less than 15 feet, in some localities 16, and on light soils 18 feet. In Berwickshire and Roxburghshire, the ridges have for a long period been 15 feet on all classes of soils—being considered the most convenient width for the ordinary manual and implemental operations. In other districts 18 feet are most common, while in some the “rod” of $16\frac{1}{2}$ feet is adopted. In some parts of Ireland the land is not ploughed into ridges at all,

being made with the spade into narrow strips called *lazy-beds*, separated by deep narrow trenches named *sheughs*. Where the plough is used, however, narrow ridges of 12 to 14 feet are mostly formed.

The modern tendency is to do away with ridges altogether, however, and to plough the ground in wide "lands" with as few open furrows as possible. Since the introduction of the string-binder and various other modern field implements it has been found that open furrows are a very great hindrance to the working of such, and therefore the fields are more often now than formerly ploughed so as to have a crown or an open furrow from 50 to 100 feet apart. A good rule is to make only as many open furrows as are necessary to run the surface-water off.

Ancient Form of Ridges.—More than half a century ago, ridges were made very broad—from 24 to 36 feet, and high on the crown—from an idea that an undulated surface affords a larger area for the crop to grow on, and that a crooked ridge like the letter S, from another mistaken notion, always presents some part of the crop in a right direction to the sun; which, although it did, removed other parts as far from it. Ridges were also made crooked to suit the lie of the land, so as to prevent the water in the furrows from gathering too great a force down-hill, and thus tend to wash away large quantities of useful soil. In parts many broad crooked ridges may still be seen; but the common practice is to have the ridges of moderate breadth, straight, and pointing to noon-day. For distinctness of description let it be understood that only a ridge of 15 feet in width is spoken of hereafter.

Feering.—The first process in the ridging of land upon the flat surface is *feering*, which is done by placing upright, in the direction of the ridges, not fewer than three poles, and as many more as are necessary (fig. 316), $8\frac{1}{2}$ feet in length, graduated into feet and half-feet, and each painted at the top of a different colour, with bright blue, red, and white, to form decided contrasts with

one another when set in line, and also with green trees and hedges, and brown ground.

Feering land is done in this manner: Suppose *a* and *b*, fig. 317, to represent the S. and E. fences of a field, of which *x* is the south *headridge* or *headland*, of the same width as the ridges—15 feet. There are two headridges in every field. To mark off the width of the headridge distinctly, pass the plough in the direction of *r e*, with a small furrow-slice lying towards *x*. The same is done along the other headland, at the opposite side of the field. Then take a pole and measure off the width of a quarter of a ridge—viz., 3 feet 9 inches from the ditch-lip, *a e*—and plant a pole at *c*. With another pole set off the same distance from the ditch, *a e*, and plant it at *d*. Then measure the same distance from the ditch, at *e* to *f*, and at *f* look if *d* has been placed in the line of *f c*; if not, shift the pole at *d* until all the three poles are in a line. The plough-staff (fig. 301), set at *f*, will answer for a pole. Then plant a pole at *g* in the line *f d c*. Before starting to feer, measure off $\frac{1}{4}$ ridge—namely, 18 feet 9 inches from *f* to *k*—and plant a pole at *k*.

To secure perfect accuracy in measuring breadths of ridges at right angles to the feerings, lines at right angles to *f c*, from *d* and *g*, should be set off in the direction of *t* and *v* by a cross-table and poles, and marked by a slight furrow drawn by the plough in each of these lines, previous to the breadth of the feerings being measured from *d* and *g* along them. Most people do not take the trouble of doing this, and a proficient ploughman renders it the less necessary; but every careful farmer will do it, even at a little sacrifice of time and trouble, to ensure perfect accuracy of work, and especially when he is feering for a seed-furrow, which fixes the rigidity of the ridge during the entire rotation of the cropping.

It is essential to the correct feering of the whole field to have the first two feerings *f c* and *k l* correctly drawn, as an error committed there will be transmitted to the other end of the field; and to attain this correctness, two persons, the ploughman and the farm-steward, or farmer himself, should set the poles.



Fig. 316.
Feering-
pole.

Only an experienced ploughman, and a steady pair of horses, should be intrusted with the feering of land. Horses accustomed to feering will walk up of their own accord from pole to pole standing before them within sight.

Now, start with the plough from *f* to *d*, where stop at the pole standing between the horses' heads, or else pushed over by the tying of the horses. Then measure with it, at right angles to *fc*, a line equal to the breadth of $1\frac{1}{4}$ ridge,

18 feet 9 inches, in the direction of *t*, which will be in the line of *kl*, where plant a pole. In like manner proceed from *d* to *g*, where again stop, and measure off $1\frac{1}{4}$ ridge, 18 feet 9 inches, from *g* in the direction of *v*, which is still in the line of *kl*, and plant a pole there. Proceed to the other headridge to the last pole *c*, and measure off $1\frac{1}{4}$ ridge, 18 feet 9 inches, from *c* to *l*, and plant a pole at *l*.

From *l* look towards *k*, to see if the

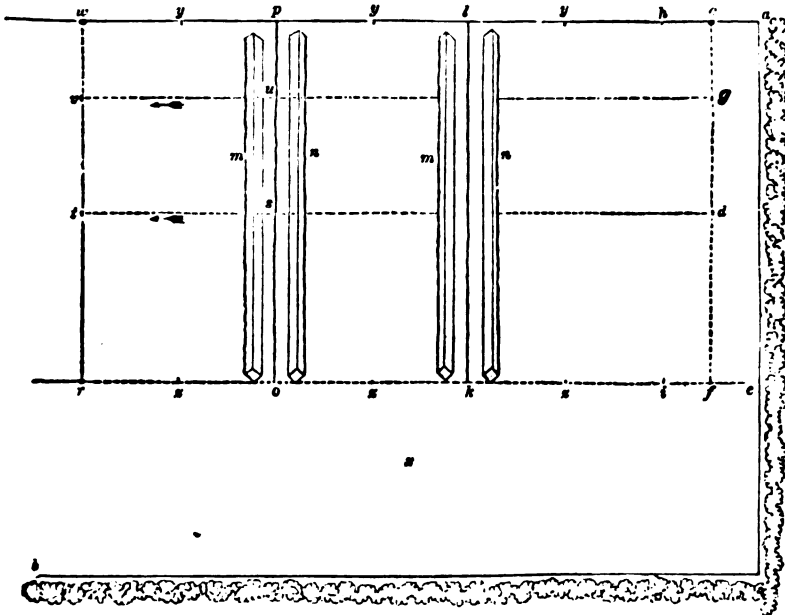


Fig. 317.—Mode of feering ridges.

a to *b* Fences of field.
s Headridge of field.

kl, op Second and third feering of ridges; *fc* first feering of ridges.
m and *n* Furrow-slices of feerings.

intermediate poles are in the line of those at *l* and *k*; if not, shift them till they are so. On returning by the furrow from *c* to *f*, obviate any deviation which the plough may have formerly made from the straight line. In the line of *fc*, the furrow-slices of the feering have been omitted, to show more distinctly the setting of the poles at *d* and *g*. The furrow-slices are shown at *m* and *n*.

Proceed in this manner to feer the line *kl*, and also the line *op*; but in all feerings after the first, from *f* to *k*, the poles are set up at the exact breadth of

the ridge, as from *k* to *o*, *l* to *p*, and again from *o* to *r*, *p* to *w*, in the direction of the arrows. And the reason for setting off *cl* at so much greater a distance than *lp* or *pw* is, that the half-ridge, *ah, ei*, may be ploughed first, and the rest of the ridges ploughed by half-ridges instead of whole.

The first half-ridge *ah, ei*, is, however, ploughed in a different manner from the other half-ridges: it is ploughed by going round the feering *fc* by always *hopping* the horses until the open furrow comes to *ae* on the one side and *hi* on the other. This half-

ridge is ploughed before any of the others are begun to.

The line *h i* then becomes the feering along with *k l* for ploughing the 2 half-ridges *z i* and *z k*, the open furrow being left in the line *z y*, corresponding to that in the line *e a*; and between these two open furrows is embraced and finished the full ridge of 15 feet *e z*, having its crown along *i h*. In ploughing these two half-ridges the horses are always *hied*.

As the plough completes each feering, the furrow-slices are laid over as at *m* and *n*. While one ploughman proceeds in this manner to feer each ridge along the field, the other ploughmen commence the ploughing of the land into ridges; and to afford a number of them space for beginning work at the same time,

the feering ploughman should be set to work more than half a day in advance of the rest. On most farms now each ploughman does his own feering, although it may be doubtful if it is usually performed so carefully as where the above method is pursued.

In commencing the ploughing of ridges, each ploughman takes two feerings, and begins by laying the furrow-slices *m* and *n* together of both the feerings, to form the crowns of two future ridges. One ploughman thus lays together the furrow-slices of *f c* and *k l*, whilst another is doing the same with those of *o p* and *r w*. These ridges are ploughed in half-ridges—that is, the half of one ridge is ploughed with the half of the adjoining ridge by always *hieving* the horses. The advan-

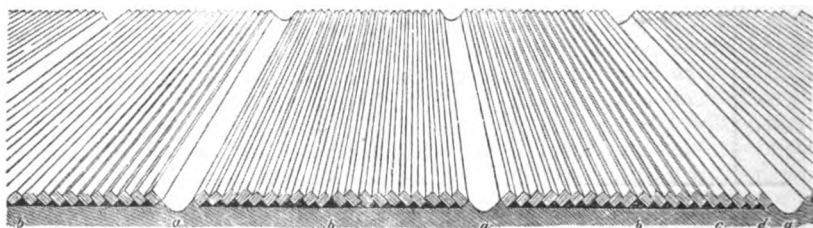


Fig. 318.—Gathered-up ridges from the flat.

- | | |
|---|--------------------------|
| a a a Three open furrows of two ridges. | b b Crown of two ridges. |
| a b Furrow-slices lying from left to right. | c d Furrow-brow. |
| b a Furrow-slices lying from right to left. | e Mould-board. |

tage of ploughing by half-ridges is, that the open furrows are made thereby exactly equidistant from the crowns; whereas, were the ridges ploughed by going round and round the crown of each ridge, one might be made narrower than the determinate breadth of 15 feet, and another broader, by a similar error of the ploughman.

Gathering up Ridges.—After laying the feering furrow-slices so as to make the crowns of the ridges at *f c*, *k l*, *o p*, and *r w*, the mode of ploughing the ridges from the flat ground is to *hieve* the horses always towards you, on reaching the headridges, until all the furrow-slices between each feering are laid over as far as the lines *y z*, which become the open furrows.

This method of ploughing is called *gathering up*, the disposition of the furrows in which is shown in fig. 318, where *a a a* embrace two whole ridges and

three open furrows, on either side of which all the furrow-slices lie one way, from *a* to *b*, and also contrariwise from *b* to *a*, until both sets of furrow-slices meet in the crowns *b b*. The open furrows *a a a* are finished off with the mould or hint-end furrows.

The *crown*, or first furrow-slices, made in gathering up—which afterwards forms the centre of a ridge or land—is made differently in different districts. Usually two very small triangular slices, 3 inches by 3 inches, are first cut up and down and about 2 feet apart, and turned in to meet one another in the centre. Then two wider and deeper ones outside these are cut and turned to lap over the top of them. Then still deeper and wider ones are ploughed outside these, till at about the third furrow the full width and depth is arrived at. The finished furrow-slices should be perfectly regular and even and level across, and a skilled workman can

make the work so perfect that the crown could not be distinguished from the rest of the ploughing. When an old open furrow already exists, it renders the work much more easy, as then a fair-sized furrow-slice can be turned over into the hollow to form the new crown straight away. In some districts, again, it is actually the custom to "plough out" two triangular slices, break them up and spread them over the untouched land, and then start the crown in this new furrow.

Number of Furrows in 15-foot Ridge.—The furrow-slices in fig. 318 are 20; whereas 10-inch furrow-slices across a 15-foot ridge would only be 18, which would be the number turned over in loose mould; but the figure represents gathered-up ridges in lea-ground, and

the mould-furrows are shown as correctly formed as the others—which they ought to be; but in ploughing lea, the mould-furrow scarcely ever measures 10 inches in breadth, most ploughmen regarding it as not forming a part of the regular ridge, but only a finishing to it.

The Finish or Mould Furrows.—The *mould* or *hint-end* furrow is made in this way: When the last two furrow-slices of the ridges *a a*, fig. 319, are laid over, the bottom of the open furrow is as wide as from *a* to *a*, and flat as the dotted line *c*. The plough goes along this wide space at *c*, and first lays over the triangular furrow-slice *b* on one side, and returning in the same furrow *c*, lays another slice of the same form *b* on the other side, up against and covering the lowest ends of the furrow-slices *a a*, by

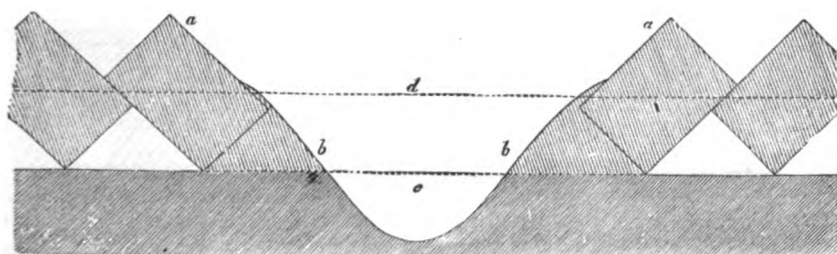


Fig. 319.—Open furrows with mould or hint-end furrow-slices.

a a Two last-ploughed furrow-slices, and *b b* Two mould furrow-slices closing up the open furrow between them. *c* Finished open furrow.

which action the ground is hollowed out in the shape represented below the dotted line at *c* by the sole of the plough. The dotted line *d* shows the place of the surface of the ground before it was ridged up, and the furrow-slices *a a*, the elevation attained by the land above its former level *d*.

Crown-and-furrow Ploughing.—*Crown-and-furrow* ploughing can easily be performed on land which has been gathered up from the flat. No feering is required, the open furrows answering the purpose. Thus, in fig. 318, let the last furrow-brow slices *d* be laid over into the open furrows *a*, and it will be found that they will just meet, since they were formerly separated by the same means; and in ploughing the ridges in half-ridges, *a* will become the crowns of the ridges, and *b* the open furrows—hence the name of crown-and-

furrow to this mode of ploughing. Its effect is to preserve the ploughed surface of the ridges in the same state as they were when gathered up from the flat.

When no surface-water is likely to remain on the land, as in the case of light soils, both these are simple modes of ploughing land; and they form an excellent foundation for drills for turnips on stronger soils, and are much practised in ploughing land for barley after turnips. But when the land for barley after turnips is to be *twice* ploughed, and it is inconvenient to cross-furrow the land,—which it will be when sheep on turnips occupy a field having long ridges, or the season is too wet to leave the land in a cross-furrow,—then the land should be so feered as, in gathering up from the flat, the crown-and-furrow ploughing may afterwards complete the ridges for the seed.

On looking at fig. 318, where the ridges are complete, it is obvious that, were they ploughed into crown-and-furrow, thereby making the open furrows *a a* the future crowns, a half-ridge would be left at each side of the field,—a mode of finishing off a field displaying great carelessness and want of forethought. When the land is to be twice ploughed, the feering, therefore, of gathering up from the flat should leave a half-ridge on each side of the field, that the subsequent crown-and-furrow ploughing may convert them into whole ridges. Thus, the first feering for gathering up should be made at *e a*, fig. 317, instead of *f c*, and every other at the width of one ridge, 15 feet. On ploughing these feerings, the open furrows will be left at *i h*, *k l*, *o p*, and *r*

w; and these will form the feerings of the subsequent crowns of the crown-and-furrow ploughing.

Casting Ridges.—Another mode of ploughing land from the flat surface is *casting* or *yoking* or *coupling* the ridges. The feering for this is done in a different manner from the two foregoing. The first feering is made in the line of *e a*, fig. 317, close to the ditch, and every other is made at 15 feet, the width of 1 ridge—as at *y z*, *y z*, *y z*. Two ridges are thus ploughed together, making a coupled ridge of 30 feet in width.

The true disposition of the furrow-slices is seen in perspective in fig. 320, which exhibits a breadth of three entire ridges, *a b*, *b c*, and *c d*, two of which, *a b*, *b c*, are cast or yoked together, and

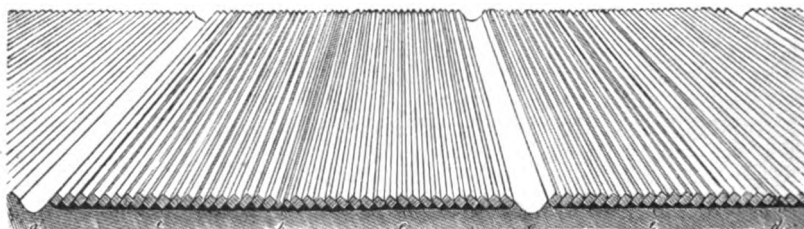


Fig. 320.—Cast, yoked, or coupled ridges.

a b One ridge with the furrow-slices lying to the right.
c b The other ridge with the furrow-slices lying to the left.

b Crown of the two coupled ridges.
c d Another ridge, with the furrow-slices lying to the right.
a and *c* Open furrows between the coupled ridges.

meeting at *b*, the crown of the coupled ridge.

Ridges thus yoked can easily be recast, by reversing the furrow-slices of *b c* and *c d* into the open furrow *c*, and converting *c* into the crown of the yoked ridge *b d*, and making the crowns *b* and *d* open furrows.

Casting keeps the land in a level state, and can most conveniently be formed on dry soils. It forms a good foundation for drilling, and makes an excellent seed-furrow on dry land. Lea and seed-furrow for barley, on light land, are generally thus ploughed. It is an economical mode of ploughing land in regard to time, as it requires but few feerings; the furrow-slices are equal, and the horses are always turned towards you. It is best performed upon the flat surface, and should the land be ploughed again, it may be recast, and no half-ridges left at the sides of the field.

Cross-ploughing.—*Cross-ploughing* is at right angles to the furrow-slices of ridges. Its object is to cut the furrow-slices into small pieces, so that the land may afterwards be easily pulverised. It is commonly executed in the spring, and should never be attempted in winter; because the altered position of the furrow-slices would retain the rain or melting snow, so that the land would remain wet. But even if cross-furrowing were executed quickly in winter, and the weather allowed the soil to be safely ridged up, the soil would become so consolidated during winter that it would have to be again cross-furrowed in spring before it could be pulverised. The object of cross-furrowing being to pulverise land, it is practised on every kind of soil, and exactly in the same manner.

It is ploughed in divisions, the feerings being made at 30 yards asunder, and executed in the same manner as for

two-out-and-two-in, fig. 321, by going round the *feerings*, *hupping* the horses constantly from you, until about half the division is ploughed, and then *hieing* them towards you, still laying in the furrow-slices towards the *feerings*, until the division is ploughed.

In cross-ploughing, no open furrow is left, it being closed with two or three of the last furrow-slices being reversed, and all existence of furrows obliterated by the plough filling loose soil into them with the mould-board, laid over and retained in that position by a firm hold of

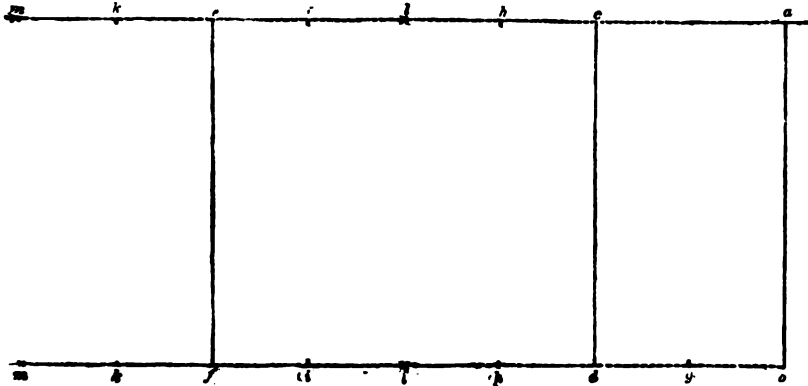


Fig. 321.—Feerings for ploughing ridges two-out-and-two-in.

c d and e f Feerings every 4 ridges or 60 feet.

l l, m m Open furrows at every 4 ridges or 60 feet.

the large stilt only. Obliteration should be complete, otherwise a hollow at the furrows would be left across the future ridges.

Bad Ploughing.—These are all instances of good ploughing with rect-

angular furrow-slices; and were they constantly executed, there would be no instances of bad ploughing, as shown in fig. 322; no high-crowned ridges as at a, caused by bringing two *feering*-slices or two open furrows too close from oppo-

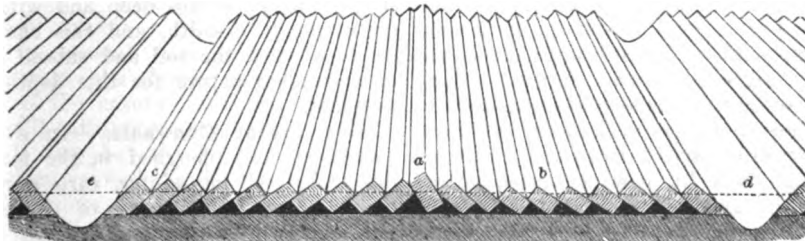


Fig. 322.—Ill-ploughed ridge.

a Too high-crowned ridge.

b Too low flank of ridge.

c Too proud furrow-brow.

d Unequal-sided open furrow.
e d Dotted line showing the former surface of the ground and the

unequal positions of the furrow-slices by bad ploughing.

site directions; no *lean* flanks, as at b, by making the furrow-slices broader than they should be, with a view to ploughing the ridge quickly, and which constitute hollows that become receptacles of surface-water to sour the land. When the soil is strong, lean flanks are so low, and become so consolidated, that they are almost sure to resist the action

of the harrows when passed across the ridge; and in light soil they are filled up with the loose mould by the harrows, at the expense of the surrounding heights. No *proud furrow-brows* as at c, by setting up the furrow-slices more upright than they should be, to the danger of being drawn bodily into the open furrow on the harrows catching them

too forcibly in cross-harrowing ; and no *unequal*-sided open furrows, as at *d*, by turning over one mould-furrow flatter than the other.

Every sort of crop grows unequally on ill-ploughed ridges, growing better on spots where the soil is most kindly, and worse on the hard portions ; but the evil effects of bad ploughing are not confined to the season it is executed, for it renders the soil unequally hard when ploughed up again.

Some are of opinion that land when ploughed receives a curvature of surface, whereas correct furrow-slices cannot give the surface any other *form* than it had before it was ploughed. If that form were curved or flat, the new ploughed surface would be curved or flat. In gathering-up a ridge from the flat ground, the earth displaced by the plough occupies a smaller area than it did by the extent of the open furrows ; but the displacement only elevates the soil above its former level, and the act of elevation cannot impart a curvature to it. True, ridges on being harrowed become curved on the surface, because the harrows draw the soil into the open furrows, having the least resistance presented to them at the furrow-brows, but the curvature thus given has no connection with the ploughing.

The steam-plough, laying all its furrows in the same direction, by means of its balanced mould-boards, dispenses with ridges and open furrows. The even surface proves advantageous in certain operations—as drilling for potatoes and turnips—and it looks well ; but in sowing grain by hand or machine, or drill, the guidance for the breadths in sowing the ridges will be missed, and some expedient must be substituted to have as sure a one as defined ridges.

PLOUGHING STUBBLE AND LEA GROUND.

When the crop has been gathered into the stackyard, the student will perceive that a large proportion of the land is in stubble, some fields containing grass, others none. The stubble which contains no grass is ploughed, the other not, and the ploughing is determined by the nature of the soil and crop.

Ploughing Stubble-land.—It is rare

that stubble-land is ploughed in any other mode in winter, than in reversing the form in which it was previously ploughed. If it had been twice gathered up on clay soil, it should now be cloven down ; if it had been ploughed crown-and-furrow, reverse the furrow-slices.

Clay Land not to be ploughed Wet.—Strong clay soil should never be ploughed in a wet state, as it will become very hard in spring, and difficult to pulverise, and even to work.

No Ploughing in Frost and Snow.—Snow should never be ploughed in under any pretext, nor the soil when in a frozen state. Ice and snow concealed under the soil remain a long time unaltered, and spring may be far advanced ere its warmth will reach them, to relieve the soil from its chilled condition.

Stubble-land ploughed Deep.—When soil is tolerably clean and dry, either by thorough-draining or naturally porous subsoil, it is desirable to plough stubble-land deep with three horses instead of two. The horses are yoked according to the arrangement in fig. 309. The form of ploughing may either be crown-and-furrow if the soil is light, or cast together when somewhat heavy. One ploughman can direct three horses well enough. The three horses may easily turn over a furrow-slice 10 to 12 inches deep and with a proportionate breadth, and this should be done when the soil and subsoil are of a suitable nature for this depth of ploughing.

Rain-water Channels.—In every variety of soil, ploughed in the forms just described for winter, care should be taken to have plenty of channels cut in the hollowest places for the surface-water to escape into the nearest ditch. The channels are first made by the plough laying them open like a feering, taking the hollowest parts of the ground, whether across ridges or along open furrows, across the head-ridge into a ditch ; and they are immediately cleared out by the hedger with the spade of all *loose earth*, which is spread over the surface. The precaution of channel or gaw cutting should never be neglected in winter in any kind of soil, the clayey soil, no doubt, requiring more gaws than the lighter ;

but as no foresight can anticipate the injuries consequent on a single deluge of rain, or a great melting of snow, it should never be neglected, and never is by the provident farmer, his great object being to keep his land in the driest condition all winter. It is certain, however, that as land is more extensively thorough-drained, it will require less gaw-cutting; but it is to err on the safe side, to have too many rather than too few of them in winter.

Deep Ploughing.—Modern experience has rather upset the faith which was formerly placed in deep ploughing. This, of course, is a relative and a very indefinite term. What one farmer has considered deep ploughing might not be so regarded by another. Not very long ago there was quite a rage for deep ploughing. It was thought, and indeed so expressed, that the steam-plough, by enabling the farmer to add a few more inches to the workable soil, would thereby vastly increase the productiveness of his land. But it was found that harm instead of good was done by burying useful soil and bringing up in its place sour unkindly subsoil. It has therefore come to be recognised that deep ploughing may easily be carried too far. What the depth of furrow should really be, depends mainly upon the character of the soil and subsoil.

As a general rule, it may be laid down that the furrow should be as deep as the nature of the soil and subsoil will advantageously permit. This rule, it may be said, is still indefinite, but deep ploughing is one of many subtle points in farm management as to which it would be worse than useless to lay down precise and unvarying directions. It must be left to practical men of good judgment to decide what is best to be done in each individual case.

Generally speaking, it may safely enough be said that for ordinary grain crops 7 inches is quite as deep as need be desired. In ploughing stubble-land as a preparation for root crops, the depth should, if possible, be much greater; and where the good soil is too shallow for deep ploughing, other means may be found of stirring of the ground to the desired depth.

Digging and Grubbing.—This stirring of the soil is effected by the digger, the grubber, or cultivator—an implement differing from the plough, inasmuch as it operates by means of tines. Tines, in action, strip the soil, and even subsoil, into ribbons, leaving the ground in the same position as it was before—that is, leaving the good soil on the surface and the subsoil still underneath. This stripping does the soil much good, by changing the relative positions of its component parts, and by opening it up so as to admit the air. Indeed, there are many soils in which the action of the digger is more effectual than that of the plough, and is therefore preferred.

Subsoiling.—Still the digger does not so thoroughly expose the under soil and subsoil to the action of the atmosphere as does the plough. Many therefore prefer the more effectual method of stirring soil and subsoil each by itself simultaneously, by means of the subsoil trench-plough, as is referred to in the section dealing with “Trench and Subsoil Ploughing” (p. 400).

Shallow Ploughing.—A preference for the rectangular furrow-slice has been evinced, and this on the safe principle that, in suitable soil, deep ploughing ought to be the rule, and shallow the exception.

Shallow ploughing for a seed-furrow is common in the case of fields of grass that have been pastured by sheep, and their droppings form too good a top-dressing to be buried by deep ploughing. The reason is plausible, but is not admitted by all to be entirely unassailable. It is well known that the roots of plants push themselves everywhere in pursuit of nutriment, even through media which afford little nourishment, in order instinctively to reach the one in which they can luxuriate. With the largest vegetable productions, as trees, this is remarkably the case; and with cereals the roots are known to extend 6 feet and more into the subsoil. Hence a strong argument for deep ploughing or stirring. In shallow ploughing weeds are apt to exert an ascendancy over the crops.

Smashing up the Soil.—Amongst the earliest and most energetic advocates of digging or stirring, as opposed to deep

ploughing, was Mr William Smith, Woolstone, England. His system was to stir the soil to the depth of 15 inches with steam-power by means of a grubber, by which he *smashed up* the soil, as he expressed it. He disapproved of the plough, and even of the principle by which it operated, and preferred the grubbing system. The steam-grubber or cultivator has certainly been more successful than the steam-plough, and it is now freely acknowledged that there was much truth in Mr Smith's reasoning, although his wholesale condemnation of the plough would not be generally supported. The chief defect in the grubbing or cultivating system is that in the main it always leaves the surface-soil at the surface, and cannot, even when it is desired and desirable, bring up any considerable quantity of fresh earth to the surface. Cultivating or grubbing, therefore, while a most useful operation, can never to any great extent supersede judicious ploughing.

Unseasonable Ploughing.—Lea should never be ploughed when affected by frost or snow, or even rime, or when soft with rain. Ice or rain ploughed down chills the ground to a late period of the season, and when rain softens the ground much, horses cut the turf with their feet, and the furrow-slice is squeezed into a pasty mass by the mould-board. Nor should lea be ploughed when hard with drought, as the plough will take a shallow furrow, and raise the ground in broad thin slabs. A semi-moist state of ground in fresh weather is the best condition of soil for ploughing lea.

Water-runs.—Gaws or water-runs should never be neglected to be cut after lea-ploughing, especially in the first ploughed fields, and on strong land, whether early or late ploughed. To

leave a ploughed field to be injured by wet weather, shows great indifference to future unfavourable consequences. No doubt, on thorough-drained land, less dread of evil consequences from neglect of gaw-cutting may be felt; but even in the best drained land it is imprudent to leave isolated hollows in fields in winter without a ready means of getting rid of every torrent of rain that may fall unexpectedly. Land which lies dry all winter may be worked a week or two earlier in spring than land which has been wet.

Headridges.—It is a slovenly practice to leave headridges unploughed for a time after the rest of the field. The neglect is most frequent on stubble-land, but it should be avoided. Ploughing headridges in winter requires some consideration.

When ridges have been ploughed in a completed form in lea, headridges of clay soils should be gathered up, and in light soils cloven down from the gathering.

A difference of opinion is entertained of the manner in which a headridge should be formed, where a great length of ridges, from opposite directions, meets in a common line across the middle of the field. The practical question is, whether these ridges should meet in an imaginary line or at a common headridge? An answer may be given thus: When ridges meet from opposite directions, they cannot be ploughed at the same time without risk of the horses encountering one another upon the common headridge; and where no headridge exists, the ridges first ploughed will be trampled upon when the others are ploughed. There should therefore be two headridges—one belonging to each set of ridges.

TRENCH AND SUBSOIL PLOUGHING.

When Mr Smith of Deanston, by his example and precept, had put the drainage of land on a systematic basis, he turned his attention to the deepening of the staple of the soil. This he found

could be effected by trench-ploughing or by subsoiling, it altogether depending upon the character of the soil which of these operations would be most suitable.

Trench-ploughing.—Trench-plough-

ing can be done in two ways. It may be done by one plough drawn by three or more horses taking an extra deep furrow, or by one plough following another in the same furrow. The latter method enables the farmer to take up an inch or two of the subsoil for mixing with the upper soil.

Injurious Ingredients in Subsoil.—But in deciding to carry out this process of taking up subsoil, to be mixed with the surface-soil, great care must be exercised. The subsoil often contains substances that are deleterious to plant-growth, and if these are brought up the soil may for a time be seriously deteriorated.

Subsoiling.—The use of the subsoil-plough is the safer practice. By it the

subsoil, without being taken to the surface, is stirred or broken up, which allows water and air to percolate through the soil, thus dissipating the injurious elements and improving the whole character of the land. Subsoiling also increases the beneficial action of drains. Air, when it enters a soil, raises the temperature, renders the dormant ingredients active or soluble; and, lastly, the operation of subsoiling increases the area for the ramification of the roots of plants.

Subsoiling can be best done when ploughing the fallow, and ought never to be attempted until the soil is perfectly dry. The subsoil ought to be broken up and not cut, which would be the case if the operation were carried out while the land is wet. The subsoiling ought to

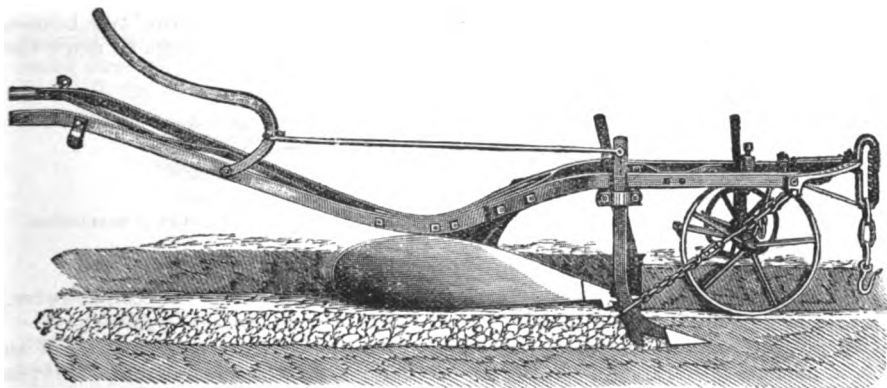


Fig. 323.—Single plough and patent subsoiler combined.

be done across the line of the drain, especially if the subsoil contains any of the numerous forms of "pan," which can be more readily broken up by following this method. It also helps the drains, as it forms ruts to each drain for the water to run in.

Trench-ploughing following Subsoiling.—After this subsoiling the land may be safely trench-ploughed when it comes next into fallow, as all the deleterious substances will have been either washed out of the soil or rendered insoluble by the action of oxygen or other elements.

Subsoil-Plough.—Various implements have been devised to descend as far into the soil as to stir the subsoil effectually, and they have obtained the name of *subsoil* and *trench* ploughs, according to their

action upon the subsoil. The subsoil-ploughs stir the subsoil lying under the upper soil without affecting their relative positions, whereas trench-ploughs commingle more or less the subsoil with the upper soil. The working of the subsoil-plough is shown in fig. 323 and fig. 324.

Economy of Trenching and Subsoiling.—One great advantage attending this mode of trenching and subsoiling is, that in thus stirring the soil in autumn the upper soil requires only to be stirred in spring by a grubber to effectually pulverise the surface and prepare it for a green crop. When a facility is put into the power of the farmer to work his land in a short time and in the most efficient manner, two good results must ensue—the entire fallow-break may be devoted

to a green crop, and a smaller horse-power will suffice for the work.

Process of Trenching and Subsoiling.—The execution of subsoil trenching with the trench-plough and subsoiler is as follows: The trench-plough, drawn by three horses, takes the lead and lays open a furrow of 10 to 14 inches deep, according to the character of the soil. When a large stone is encountered, the horses are not urged, but taught to stand still until the ploughman marks its spot. He passes the stone the best way he can, and goes on with the ploughing until he meets with another stone. Two labourers follow the plough, one with a spade and another with a hand-pick or crowbar, to turn out the stone upon the ploughed land.

The subsoil trench-plough, provided with four horses, the extra ploughman walking beside the foremost pair, follows

in the same furrow, and goes 6 or 7 inches deeper into the subsoil. Should a stone be encountered, the extra ploughman marks it, and he also helps to turn the horses at the end of the landing.

These horses are also taught to stand when coming against a stone. A reckless practice too common is to urge the horses on when encountering a stone, running the risk of breaking the plough, straining the horses, and snapping asunder some part of the harness. The two labourers are at hand to bring up the deeper stone to the ploughed surface.

An acre is stirred every day with these two ploughs in autumn; the horses are not oppressed, the men are quite able for their part of the work, and the work done is effectual, satisfactory, and permanent.

Perhaps a better plan in medium land is to start the plough with two horses, and let the man have pegs to mark the

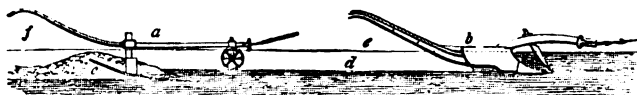


Fig. 324.—Conjoint operation of the common and subsoil trench-plough.

b The plough going before.

a Trench-plough following after, with bearing-wheel.

c Tail-board over which the subsoil falls 9 inches.

a Depth of furrow by the plough, 10 or 12 inches.

e Surface of ground.

f Stilts of trench-plough.

stones, the subsoil-plough following with three horses. The land-fast stones can be removed then at the convenience of the farmer.

Such a subsoiling is sufficient for a lease of nineteen years, and even longer. The stones which can be lifted by hand are carted off the surface. Some boulders may require blasting with gunpowder on the spot, and others have to be drawn off on a sled.

This operation is most effective a few years after thorough drainage. The subsoil *trenching* is not required in a naturally porous subsoil, but *deep stirring* of the surface-soil is a necessity on every class of land.

Hand Trenching.—Trenching with the fork is more efficient than ordinary subsoil-ploughing as regards the stirring of the soil and subsoil. It is also a more perfect operation, inasmuch as it exposes the subsoil to view, breaks every portion of it to a greater depth, and frees it of every stone that, from its size, would injure the implements in any future

operation of culture. The cost, however, is great, and the process a slow one.

"In digging light soil, or any soil in a friable state, the spade should be driven to the head into the ground by one pressure of the foot, and thus twenty cuts may be made in one minute. In Ireland one perch of soil is dug 9 inches deep, at the same cost that half a perch of drain, $2\frac{1}{2}$ feet deep, is cast out; but more wages should be obtained for casting drains than digging soil, to provide against the extra tear and wear of shoes and clothes, and the risk of injuring health by cold and wet. The most economical way of digging a large piece of land is to set from twenty to thirty diggers at work together, at so much for one acre, and place a confidential man over them to see that every spadeful is properly formed and turned over."¹ A spit by a common spade No. 5, weighing 8 or 9 lb., should be 7 or 8 inches broad, 9 inches deep; and the earth weighs 17

¹ Yule's *Spade Hush.*, 86, 2nd ed.

lb. In digging one perch of ground, the spade has to be thrust in 700 times, and 11,900 lb. of earth is lifted. To dig one acre takes 112,000 spadefuls, weighing 850 tons, and adding the weight of the spades, 1278 tons: the space travelled over in doing this is fourteen miles. An able man can dig 10 square perches in one day, provided the soil is light and moderately moist.

Bastard Trenching.—Allotments and small holdings are of little use to their cultivators unless the land is made the most of; and it is not too much to say that this method of treating the soil will double the yield of crop obtained by ordinary tillage. On all poor, shallow soils, and even on soils not so poor, but resting on a pan of tenacious clay that has never been broken up, it is essential, and the work very soon repays itself. Should the soil be light, the roots will work down to the cool lower stratum and find all the moisture necessary for their support; if a clay soil, then bastard trench-

ing is even more needful, one advantage being that during a wet season any excess of rainfall percolates downwards more readily, and the surface-soil does not become water-logged, as is so often the case where heavy land is merely dug over one spit deep.

The method of bastard trenching is as follows: Open out a trench 18 inches or more in width, and one spade deep; then, by fork or mattock, raise up and stir the subsoil to a further depth of 8 or 12 inches; on the top of this throw the next top spit, and so on to completion. If a good dressing of dung can be placed on the stirred subsoil before turning over the next spit, so much the better. Where this cannot be done, and the land being broken up is under grass, it is a good plan to skin off the sod, and place it grass down on the subsoil, at the same time chopping it across with the spade into small pieces, which in many cases will serve as well as a dressing of manure.

THE APPLICATION OF STEAM-POWER TO AGRICULTURE.

In nearly all industrial operations the use of steam-power has had the effect of increasing, and thus quickening and cheapening, production. In many cases it has supplanted, and in most cases it has supplemented, muscular effort. It has thereby brought into use and made profitable that which otherwise might have been of little commercial value.

In the early part of the nineteenth century the machinery of the farm was of the most primitive description. The land was cultivated by implements made by the local smith and wheelwright. The hay and corn crops were harvested by the scythe and sickle. The horse implements were clumsy and heavy of draught, and the ordinary labour of the farm had to be supplemented in the summer and autumn by large contingents of casual labourers, who came over from Ireland or down from the highlands of Scotland. These men generally arrived for the hoeing of turnips and potatoes, and remained for the hay and corn har-

vests. As a rule, they took home with them a substantial reward of their industry, which helped them to tide over their winter on the Highland croft or the little Irish holding, as the case might be.

The Dawn of Agricultural Engineering.—But in the early Victorian era, when the inventions of James Watt were bearing practical fruit, and Stephenson developed his locomotive, a great change was also effected in agricultural appliances. The steam-engine was pressed into the service of the farmer. A new branch of engineering was created. Some of the more enterprising local makers, who had hitherto looked for a market at home, took advantage of the facilities provided by the network of railways which soon traversed the face of the country, to look afield for new customers. Gradually what was once a local trade swelled out into a national one. Thus arose many of our present great agricultural engineering firms, whose produc-

tions are well known in all parts of the world. The large agricultural societies, notably the "Royal" of England and the "Highland" of Scotland, commenced holding their shows in different parts of the country. By the offer of prizes for improved machinery they induced manufacturers to perfect their productions, and the result was a surprising development both of steam and horse machinery. Field implements for horse-power naturally came first, and the antiquated and inefficient appliances of the past soon gave place to others, lighter in draught, and capable of doing more and better work with a smaller expenditure of power.

Early Days of Steam-Power for Farms.—Following hard upon the improvements in horse implements came the introduction and development of steam-power for the heavier work of the farm. In the early days of steam the engines were generally stationary. The cost of buildings, when added to the price of the engine and boiler, made them very expensive. As a rule, they were heavy and cumbersome. They worked at a slow speed with a low pressure of steam, and consequently large cylinders with proportionately large boilers were required to develop the necessary power. The modern steam-engine works at a quicker speed, with a higher steam pressure, and the engine and boiler are frequently combined in one, either portable or semi-portable, so that the cost of buildings and foundations and fixing are reduced to a minimum.

Other Forms of Power.—But steam-engines are not now the sole motive-power at the command of the farmer. Since 1880 or so two new forces have been placed at his disposal. One is the gas- or oil-engine, and the other is electricity. There has also been a wonderful and useful revival of the application of wind-power. This, by utilising one of the most erratic forces of nature, has proved invaluable in the provision of water-supply to homesteads in all parts of the country. It will therefore be convenient to divide this article into four sections—viz., (1) Steam and the steam-engine; (2) Gas and oil-engines; (3) Electricity; and (4) Wind-engines.

I. STEAM AND THE STEAM-ENGINE.

FUEL.

Before proceeding to deal with the economical production and utilisation of steam, it will be advisable to consider the efficiency of the various kinds of fuel, the theory of combustion, and the properties of steam.

Fuel—Combustion—Properties of Steam.

Coal.—Coal, of course, takes the leading place as a material for generating heat. In this country we have many varieties and qualities of this substance, but the purest and best is that found in the South Wales coal-field. Not only does the evaporative power of different coals vary greatly, but the useful effect which is obtained from the same qualities of fuel also varies with the construction of the furnaces, the conditions under which they are consumed, and the amount of air which is admitted in each case to support the combustion.

Oxygen and Combustion.—The great supporter of combustion is the oxygen which is ever ready to hand in large quantities in the atmospheric air. This combines with the combustible constituents of the fuel at a sufficient temperature, and when this combination takes place in proper proportions, perfect combustion is the result.

Amount of Air for perfect Combustion.—The amount of air necessary for the complete combustion of 1 lb. of coal is $11\frac{1}{2}$ lb., or 150 cubic feet. It is therefore necessary, in order to secure full economy, that there shall be sufficient draught to cause this quantity of air to pass through the fire. In the absence of a sufficient supply of air, not only is smoke emitted, but carbonic oxide is formed, which carries away with it in a gaseous state, and unutilised, a large portion of the heating qualities of the fuel.

On the other hand, too great a draught causes an excessive quantity of air to pass through the fire, which is also a source of waste, as the heating of a greater volume of air than is necessary for the perfect combustion of the fuel absorbs a large

amount of heat which should be applied to heating the water in the boiler and converting it into steam.

Kinds of Fuel compared.—For convenience of stating and comparing the relative heating-value of different kinds of fuel, the quantity of water which can be evaporated by 1 lb. of the particular fuel from a temperature of 212° is generally taken as a standard, and by it the following theoretical values of different kinds of fuel may thus be expressed:—

Description of fuel.	Pounds of water evaporated from a temperature of 212° by 1 lb. of the fuel.	Units of heat contained in 1 lb. of the fuel.
Petroleum	22.0	21,260
Best Welsh coal (Ebbw Vale)	16.8	16,240
Patent fuels (average)	15.6	15,100
Best Newcastle steam coal	15.3	14,820
Scotch coal	14.7	14,200
Coke	13.0	12,560
Dry peat	10.0	9,670
Dry wood	7.5	7,250

These theoretical values are, however, never realised in practice. The best recorded results fall at least 25 per cent short of the above standard, and in most cases it will be found that not more than 50 per cent of the theoretical value of the fuel is being utilised for the production of steam.

Heat the Source of Energy.—Heat, which is the great agent in the production of steam, may be said to be the source of all energy. It is many years since scientific men demonstrated this truth, but only in recent years has it been accepted, and the relation between heat and work recognised by practical men. The English standard unit of heat is the amount of heat necessary to raise the temperature of 1 lb. of water 1° Fahr. Joule and others proved by experiment that a certain force, represented by a weight of 772 lb. falling a distance of 1 foot, was equivalent to an expenditure of heat sufficient to raise the temperature of 1 lb. of water by 1° Fahr.; so that the

unit of heat may be described as the equivalent of 772 foot-pounds.

"Foot-pound" and Horse-power.—The "foot-pound" is the convenient expression fixed upon by James Watt as the unit of work, and the meaning of the expression is simply "one pound lifted to a height of one foot in one minute." Watt estimated the work of one horse to be equal to 33,000 of these units of work,—that is, 33,000 lb. raised to a height of 1 foot in one minute, or 330 lb. raised 100 feet in one minute, or 1000 lb. raised 33 feet in one minute—and so on. This standard is still accepted, and in all mechanical calculations 33,000 "foot-pounds" is taken as the actual power of a horse.

Actual and "Nominal" Horse-power.—It may be here stated that there is a great difference between the actual horse-power of a steam-engine and the "nominal" horse-power. The former is a clearly defined duty, but the latter is merely a trade-term, vague and indefinite. It is generally based upon the diameter of the cylinder of the engine, without regard either to the pressure of the steam or the speed of the piston. Moreover, almost every maker of engines has his own standard of piston-area per nominal horse-power, thus increasing the vagueness of the term.

The Royal Agricultural Society of England probably gives the most sensible proportion of piston-area—viz., 10 circular inches per nominal horse-power. By giving the area in circular inches, the power may be more easily calculated than in square inches, as of course it is obtained by merely multiplying the diameter of the cylinder by itself. Thus a 9-inch cylinder gives 81 circular inches, which, divided by 10, is equal to 8.1 nominal horse-power. A 10-inch cylinder gives 10 nominal horse-power, and a 12-inch cylinder 14.4 nominal horse-power.

Amount of Fuel per Horse-power.—It will be seen by reference to the above table that a pound of Welsh coal contains 16,240 units of heat, and as each unit of heat is equivalent to 772 foot-pounds, the theoretical value (or duty) of one pound of this description of fuel is 12,537,280 foot-pounds, equal to about $6\frac{1}{3}$ actual horse-power per hour. Hitherto, however, the best engineers have been entire-

ly unable to construct engines which would give off anything like the amount of work due to this theoretical duty of the fuel. In the very best recorded experiments, the very best duty got out of the best fuel under most favourable circumstances has been about 1 horse-power per hour from 1 lb. of coal. This is equal to only 1,980,000 foot-pounds, or less than one-sixth of the theoretical value of the coal. The data published by the Royal Agricultural Society of England have been considered unreliable, in consequence of the inaccuracy of their testing apparatus; but independent scientific tests give about twice the above consumption as necessary for the best constructed agricultural engines (*viz.*, about 2 lb. of coal per horse-power), which thus give off only about one-twelfth of the theoretical duty of the fuel.

Dissipation of Heat.—The causes of this enormous loss of energy are legion, but they are mainly due to the waste of heat in the various processes of combustion, and the loss of heat by radiation. No sooner has the heat been generated by combustion, than it manifests a tendency to disappear. Where the furnace in which it has been generated has free communication with the atmosphere, the heat speedily escapes and dissipates itself in the surrounding air. Where it cannot escape so freely, it imparts itself with greater or less readiness to whatever comes in its way. A bar of cold iron thrust into a hot fire speedily robs the fire of some of its heat, which it goes on absorbing until it becomes red-hot, or even burnt away. If the red-hot bar be taken out of the fire and held in the open air it gradually gives off its heat to the surrounding atmosphere, which it warms by *radiation*.

Radiation is the term used to describe the action of the heat in passing off from a heated body into the atmosphere. If the bar be quickly plunged into a trough of cold water it is speedily robbed of its heat, which is absorbed by the water, which is thereby increased in temperature to the extent due to the amount of heat absorbed.

Conductors of Heat.—Some materials are better conductors of heat than others. For example, a bar of copper, which is a good conductor, plunged into

a hot fire, would absorb a greater amount of heat in a given number of seconds than a similar-shaped body of a more refractory material, such as fireclay.

Economical Use of Heat.—It will thus be seen that in order to get the best duty out of fuel it must be properly consumed, so that the utmost possible amount of heat may be generated, and the heat must be so utilised that the greatest evaporative duty may be got out of it. For this purpose boilers are designed and fixed in such a way that the heated gases shall be kept in close contact with the boiler-plates or heating-surfaces for as long a period as possible, so that they may communicate as much as possible of their heat to the water in the boiler before they are allowed to escape into the atmosphere.

Preventing Loss by Radiation.—But after the heat has been generated from the fuel, and effectually applied to the production of steam, it is of the utmost importance that all loss of heat by radiation from the boiler, steam-pipes, and cylinder of the engine should be prevented, as every unit of heat so lost is equivalent to a loss of energy equal to 772 foot-pounds. No part of the boiler should therefore be exposed to the cooling action of the atmosphere, but all such exposed parts, as well as the steam-pipes and cylinder, should be carefully covered over with some non-conducting material, so as to prevent as far as possible all loss of heat, and consequent waste of fuel.

High-pressure.—High-pressure steam—*i.e.*, from 80 to 180 lb. on the square inch—is now universally employed in all first-class engines, for the reason that only a comparatively slight extra amount of fuel is necessary to raise a cubic foot of steam to a pressure of 120 lb. on the square inch beyond what is necessary to raise it to 45 lb. on the square inch. The power exerted by high-pressure steam is not only enormously greater to begin with, but the energy it exerts by its expansive power, after the admission to the cylinder has been arrested or cut off, is very great as compared with the lower pressure.

Condensing Waste Steam.—During the process of expansion the steam is not only exerting a considerable energy, but

it is parting with a proportionate amount of its heat, which decreases in a due ratio with the pressure. Nevertheless, when the utmost has been got out of the steam by expansion, there still remains in it a certain amount of heat, which may be used for heating the feed-water on its way to the boiler. Or, better still, it may be conducted by means of pipes to a condenser, where its remaining heat is finally absorbed by the water of condensation. The result of this condensation is, that a vacuum is formed in the cylinder (on the opposite side of the piston from that upon which the steam-pressure is acting), which is equivalent to a force equal to the pressure of the atmosphere (say 15 lb.) exerted on every square inch of piston-area.

Condensing Engines.—For fuel economy, therefore, high-pressure steam, used expansively and condensed, will give the very best result. The principal obstacle in the way of the universal use of condensing engines is the necessity for a considerable supply of cold water. The action of the condenser, although not fully understood by many steam-users, is extremely simple. The waste-steam pipe, instead of conducting the exhaust-steam into the atmosphere, conducts it into a small chamber rather more than half the cubic capacity of the cylinder, where, on entering, it is met by a stream of cold water, which immediately cools it and causes it to *condense*. In other words, the condensing chamber exactly reverses the action of the boiler in which the water was originally converted into steam. The stream of cold water absorbs nearly the whole of the heat contained in the exhaust-steam, which then ceases to be steam, and resumes its original form of water. But the space occupied by the steam in its vapoury form is many times greater than the bulk which it assumes on resuming its watery form; so when the steam is condensed the most of the space previously occupied by it becomes void, and a vacuum is formed which exerts a suction on the side of the piston from which the steam had been exhausted, and consequently exerts a power auxiliary, and sometimes superior, to that due to the pressure of the steam.

If a perfect *vacuum* could be obtained,

the force of the suction due to it would as stated be equal to the pressure of the atmosphere. A perfect vacuum is, however, never attained in steam-engine practice. The nature of the vacuum is generally expressed by the height of a column of mercury. Thus the weight of the atmosphere and the power of a perfect vacuum would both be equivalent to a column of mercury 30 inches high. A vacuum equal to 27 inches of mercury is a usual thing in fairly efficient condensing engines.

The use of a condenser involves a little extra first cost, and a few extra working parts, but these are of little importance in comparison with the economy of fuel which results from condensation. The extra parts consist of the condenser itself, with an air-pump, and the necessary valves in connection therewith. It will be easily understood that in a very short time the influx of cold water, and the water resulting from the condensed steam, would soon fill up the condenser and choke it. Some means must therefore be taken to get rid of its contents, which are pumped out by the air-pump. In small engines, up to, say, 50 horsepower nominal, the condenser may be most conveniently arranged behind the cylinder, and in a line with it, so that it can be worked by a tail rod from the piston. This rod passes through the back cylinder cover, and is coupled up direct to the bucket of the air-pump, forming a very simple, neat, and effective arrangement.

THE BOILER.

The function of a boiler being to generate steam, its efficiency is estimated by the rapidity with which it does this duty, and the economy of fuel with which the result is obtained. The form of the boiler—its proportions—the nature, extent, and disposition of the heating-surfaces—have a most important bearing upon its efficiency. The greater the surface of the boiler exposed to the action of the fire and heated gases, the greater will be the quantity of water which will be evaporated by it. The comparative efficiency of steam-boilers is approximately proportional to the rel-

ative area of the heating-surfaces which they present to the action of the fire, and the area of the grate upon which the fuel is to be consumed.

Egg-ended Boilers.—Amongst the earlier forms of steam-generator used with agricultural engines was that known as the cylindrical or "egg-ended" pattern. But as this type of boiler is now nearly obsolete, and never likely to be again generally used, it is not necessary to occupy space in describing it. It was simple in construction and comparatively safe in the hands of ignorant or careless attendants, but it was extravagant of fuel, having only from 5 to 7 square feet of heating-surface per nominal horse-power.

Cornish and Lancashire Boilers.—A much more economical and altogether preferable form of steam-generator is that known as the "Cornish" or "Lancashire" type. These, like the former, consist mainly of an outer cylindrical shell of stout iron or steel plates. They have flat ends, and may have one or two large tubes or flues running through their whole length. The outer shells of these boilers vary from 12 to 30 feet in length, and from 4 feet 6 inches to 9 feet diameter. The diameter of the flues varies from 2 feet to 3 feet 6 inches, according to the size of the boiler. The flues contain at one end a fire-grate, with fire-door and other necessary fittings. They are consequently fired internally. The heated gases pass along the interior of the tubes or flues as far as the end of the boiler, and return underneath in a single or double brickwork flue, so that a much larger surface of the boiler-plates is exposed to the action of the flame and heated gases in these boilers than is possible in those of the externally fired description. The heating-surface may also be considerably increased by inserting in the flues beyond the fire-grate and at short intervals a series of cross tubes, or "Galloway tubes" as they are sometimes called. These consist of conical tubes, varying in diameter from 5 or 6 inches at one end to 10 or 12 inches at the other. They are placed transversely in the main flues at different angles, so that they obstruct the free passage of the heated gases. These impinge against the cross tubes, which are of course full of water, constantly exposed to the

fiercest action of the heat; and the effect of a number of these cross tubes fixed in the flues of a Cornish or Lancashire boiler is to greatly increase its evaporative efficiency.

These boilers are generally fixed in brickwork seatings, and they are known as "Cornish" boilers when they have but one flue, and as "Lancashire" when they have two. In both classes of boiler the best practice is to allow about 14 square feet of heating-surface to each nominal horse-power. If properly constructed, the wear and tear upon these boilers is not at all excessive. On the other hand, if badly designed, or if the water-supply contain lime or other impurities in suspension or solution which may be precipitated by heat, they are somewhat more difficult to keep clean internally than the old-fashioned "egg-ended" boilers.

Objection to Brickwork Seatings.—

The brickwork seatings are a considerable source of wear and tear in both these classes of boiler, as they prevent external examinations being conveniently made, so that in the event of leakage, corrosion may go on for years before being discovered. Indeed it often happens that it is not discovered until too late, and after fatal consequences have resulted both to the boiler and its attendants. Every steam-boiler ought to have both its outer and inner surfaces easily accessible for periodical examination, so that in the event of corrosion taking place, it may be speedily attended to and arrested.

Vertical Boiler.—Another class of steam-generator largely used in agriculture is that known as the vertical boiler. It has the advantages of occupying very little space and being very cheap, although it is by no means economical of fuel. The outer shell of these boilers consists of a plain vertical wrought-iron or steel cylinder, containing an internal circular chamber or fire-box somewhat smaller in diameter than the outer shell, so that the whole surface of the fire-box is continually surrounded by an envelope of water, to which the heat is communicated directly through the plates of which the fire-box or chamber is formed. From the centre of the crown of the fire-box a vertical flue or uptake rises, and passes

through the flat or convex plate which forms the crown of the outer shell of the boiler. This pipe not only serves as a chimney, but acts as a stay to prevent the pressure of steam in the boiler from depressing the crown of the fire-box, or bulging outwards the crown-plate of the boiler. It will thus be understood that the vertical boiler gives a greater proportion of *fire-box* heating-surface (which is the most valuable of all) than either of the two previously described classes of boilers. Unfortunately it gives us very little else than fire-box heating-surface, as, except for the short length of uptake already described, and which passes through the water and steam space of the upper part of the boiler, it presents no other heating-surface whatever.

In order to make up to some extent for this deficiency, it is usual to fix in the fire-boxes of these boilers what are known as "cross tubes." These resemble in some respects the "Galloway tubes" already described. They consist of hollow iron tubes, 8 or 9 inches in diameter, passing through the interior of the fire-box from one side to the other at different angles, so that they are constantly exposed to the full heat of the interior of the fire-box, and by promoting circulation of the water greatly increase the efficiency of the boiler as a steam-generator. These tubes are, of course, always full of water, being in communication with the interior of the boiler. There is, however, a limit to the number which can be got into a boiler, and even in the most favourable cases the heating-surface in this class of boiler seldom exceeds 10 square feet per nominal horse-power, which is a very small allowance, and accounts for the low evaporative duty obtained from them.

Hundreds of patents have been taken out for improving the efficiency of vertical boilers. Some, such as the Field tubes, have been very successful, but few are generally practicable, and most are of no value whatever.

Tubular Steam-generators.—Many leading engineers on both sides of the Atlantic have bestowed much attention upon the construction of steam-generators, built up of tubes of comparatively small diameter so arranged that, while the inside of the tubes is filled with

water, the outer surfaces are exposed to the fierce heat of variously arranged furnaces. These boilers have the advantage of extraordinary strength, and wonderful rapidity in the generating of steam. In large electric-light stations and other places where an enormous amount of steam is required they are largely used, but they do not possess any particular merits for agricultural purposes.

Boiler-mountings.—Whatever kind of boiler is used, it is of the utmost importance that the mountings should be both sufficient and efficient. No respectable boiler-maker would now turn out a boiler without double safety-valves, safety fusible plug, steam-pressure gauge, water-gauge to show the level of the water in the boiler, and test-cocks to check the working of the water-gauge, which is liable to get choked with dirt, and so mislead the attendant. A man-hole as large as possible should be provided on all boilers to give easy access for examination and repairs. These man-holes were formerly simply an oval hole cut in the top or side of the boiler. No compensation was made for the large amount of material cut away to form this hole, which naturally considerably weakened the structure of the boiler, and has thereby caused many explosions. In all cases the man-hole should be strengthened by being flanged inwards or by riveting a stout iron ring round the opening, or, better still, by having a strong cast-steel or wrought-iron man-hole mouthpiece riveted round the opening, having the cover bolted to the top flange.

Proportions of the Fire-grate.—A very important point in steam-boiler economy, and one which is very often overlooked in the fixing and working of steam-boilers, is the proportion of fire-grate, the thickness and length of the fire-bars, and the spaces between them. In practice it is a disadvantage to have a fire-grate longer than 6 feet, and the width and consequent area of course depend upon the size of the boiler, and the amount and quality of the fuel to be consumed. The following proportions of grate area, per nominal horse-power, may be taken as approximately suitable for the different boilers having the respective amounts of heating-surface already given:—

Cornish boilers should have about 1 square foot of grate area per nominal horse-power.					
Lancashire "	"	1	"	"	"
Vertical "	"	1	"	"	"
Loco-type multitubular do.	"	$\frac{3}{8}$	"	"	"

As a general rule, fire-bars $\frac{3}{4}$ inch thick, with $\frac{3}{8}$ inch fire-spaces between them, give a very fair result; but narrower bars and still narrower spaces may be used where the fuel is good and clean, and where a high evaporative efficiency is aimed at.

Skill in Firing.—With all boilers the efficiency very much depends upon the skill or otherwise of the stoker. This was shown in a marked manner at the trials of steam-engines held by the Royal Agricultural Society of England at Newcastle in 1887, where the difference in fuel economy which could be attained by skilful firing, as compared with careless or reckless firing, was most manifest.

In an ordinary way a thin fire, say 4 or 6 inches thick, frequently replenished with fuel, will give a much better evaporation per pound of coal than a thick fire replenished by larger quantities at long intervals.

Wear and Tear in Boilers.—A very important matter for the consideration of users of steam-boilers is the question of wear and tear. No doubt certain boilers are more economical than others in this respect. It must, however, be borne in mind that the treatment which boilers receive at the hands of their attendants in nearly every case determines the amount of wear and tear. Many boilers which have been at work for years in the hands of careful men show no signs of depreciation further than those due to natural causes, such as corrosion, &c.; while others of similar construction, which have been subjected to careless treatment, will have cost a large amount for repairs in the same time.

Weak Points.—It is important that boiler-users should make themselves acquainted with the weak points of their construction, so that they may know where to look for signs of wear and tear.

Corrosion in Built-in Boilers.—In the externally fired description of boiler, the natural limits to the lasting qualities are those of corrosion, and wear and tear from expansion and contraction. The former may go on for years unsuspected and undiscovered. The boiler being em-

bedded in a huge pillar of brickwork, with a very small portion of its surface exposed for examination, may be secretly eaten almost through before the owner's attention is directed to it. Cases of such corrosion are extremely common, and account for a great many fatal explosions. Should there be a leaky rivet or joint in any of the surfaces covered by the brickwork, the water which escapes serves to keep the brickwork seating damp, and the corrosion goes on very quickly, and will soon eat through the boiler-plates, no matter how thick they may have originally been.

Expansion and Contraction.—The wear and tear from expansion and contraction is one which cannot very well be guarded against. It is due to the property of the metal of which the boiler is made to expand under heat and contract when cooled. In externally fired boilers, that portion subject to the influence of fire naturally becomes heated before the other portions which are more remote from the action of the fire. The boiler being thus hot on the under side and cold on the top, becomes considerably strained, inasmuch as the underside has been elongated a little, causing a buckling or bending action. Then, again, when the fire has gone out, and the boiler has cooled down, the parts resume their normal position, and the strain due to the buckling action of the boiler ceases. This expanding and contracting action (slight though it may be), repeated at frequent intervals, has a very marked effect upon the plates of which the boiler is made. They not only become brittle and liable to crack, but in many cases the cracks quickly manifest themselves, and it is no uncommon thing to find many of the plates dangerously cracked between the rivet-holes. The effects of expansion and contraction are more observable in the flues, where the heat of the fire is most active.

Corrugated Boiler - flue.—Many plans have been tried for giving a certain amount of elasticity to the flues, so that when they become heated and com-

mence to expand, they should do so without damaging either themselves or the ends of the boiler to which they are attached. Amongst these, the most successful is undoubtedly the corrugated boiler-flue, perfected by Mr Samson Fox, whose name will always be associated with this particular form of furnace. This form of flue has also the great advantage of strengthening the tube to resist collapse from the pressure inside the boiler, and increases the area and evaporative value of the heating-surface.

Internal Tear and Wear.—The action of internal corrosion is a serious factor in "Cornish" and "Lancashire" boilers. This is due to the difficulty of keeping the inside of the boiler perfectly clean and free from sediment. In internally-fired boilers there is also a source of wear and tear due to the burning of the fire-box plates, caused by scale and sediment lodging upon the plates in contact with the fire. Wherever the sediment lodges, it keeps the water away from contact with the plates, which are naturally quickly destroyed. The nature of the iron is speedily burnt out of it, causing the plates to crack in all directions.

"Grooving."—A very frequent source of failure in all kinds of boilers is that known as "grooving." The causes of this action are most difficult of explanation, but the fact remains that the internal examination of a boiler will often reveal deep grooves in the plates forming the outer shell. Sometimes this action takes place on the bottom plates of the boiler, and sometimes at and around the water-line. The grooves are sometimes longitudinal, sometimes transverse. They are often so deep as to cut nearly through the plates, and occasionally so narrow that they can be observed only by very carefully scraping all the scale from the surface of the plates. The appearance of the groove sometimes shows a clean V groove, as sharp as if it had been cut in with a chisel.

Certain kinds of water are supposed to have more tendency to cause this action than others, but in many cases it is certainly due to the racking strain arising from the expansion and contraction already referred to. In every case it is a source of great danger, and emphasises the necessity of periodical internal as

well as external examination of all boilers.

Soft Water best for Boilers.—The effect of different kinds of water upon the tubes of a boiler of the locomotive multitubular type is very marked. Soft water, of course, is the best; and where this can be obtained, the life both of the tubes and the shell of the boiler will be very long. In other cases where the water contains injurious acids, the destruction of the tubes and outer shell may be very rapid. Deposits of scale and dirt upon the tubes and in the annular water-space surrounding the fire-box are a frequent cause of premature failure in boilers—causing the material to burn and crack, as already described in connection with the other descriptions of boiler.

Neglect of the precautions suggested by everyday experience—such as failing to keep the boiler properly washed out, and allowing the accumulation of solid matter in the water-spaces—speedily causes overheating and excessive wear and tear.

Periodical Inspection.—Having thus described the principal kinds of boilers used in agriculture, and referred to the causes of failure, and indicated where such failures may be looked for, and how they may be identified, we strongly recommend the periodical examination of all steam-boilers, whether employed in agriculture or not. There are numerous respectable boiler insurance companies who for a small annual premium will not only undertake periodical inspection, and furnish regular reports of the condition of the boiler, but will, in the event of a failure, make good not only the damage to the boiler but to the adjoining property within the limits of the insurance policy. These periodical inspections not only tend to prevent explosions, but relieve the owner of a serious moral obligation in the unhappy event of an accident involving serious consequences to life and limb.

CONSTRUCTION OF THE STEAM-ENGINE, AND THE ACTION OF THE STEAM.

Before proceeding to describe the various kinds of steam-engines used in agriculture, it may be well to explain briefly the action of the steam. The

economical use of steam is quite as important as its economical production, for it would be manifestly absurd to take great pains with the design and construction of boilers to generate steam economically, and then, by the use of badly designed or badly constructed engines—by wastefully using it in the process of converting it into useful work—to lose all the benefit which had been gained.

After having been compressed in the boiler to the requisite pressure, the steam is conveyed in pipes to the motor or engine by which it is to be utilised. Owing to the rapidity with which steam parts with its heat, these pipes, whether long or short, should be carefully covered with some non-conducting material, so that the loss by radiation and consequent condensation in the steam-pipes may be

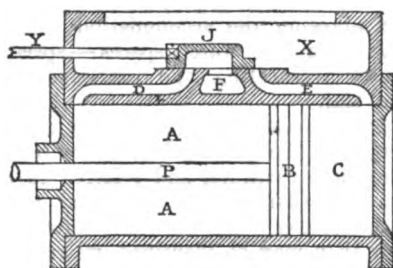


Fig. 325.—The steam-engine cylinder.

reduced to a minimum. The motor or engine consists primarily of a cast-iron cylinder in which the steam exerts its force, and of the various moving parts by which that force is converted into useful work. The cylinder of the steam-engine, which is shown at A in fig. 325, is bored out to a perfectly smooth surface. A piston or plug (B) is made to fit accurately inside the cylinder, and is fitted with expanding rings, so that the pressure of steam can exert its force on either side without blowing past the piston. The steam is admitted alternately on different sides of the piston, and by its pressure it forces the piston to move from one end of the cylinder to the other, thus giving a reciprocal motion to the piston-rod P. The distribution of the steam, whereby it is alternately admitted to the opposite ends of the cylinder, is regulated by a small slide-valve J, working in the steam-chest X of the cylinder, which receives

the steam from the steam-pipes in which it was conveyed from the boiler. The slide-valve, which is moved back and forward by means of a rod Y, not only admits the steam at one end of the cylinder, but allows it to escape out of the other end after it has done its work.

In the sketch, the valve J is shown in such a position that there is a free communication from the steam-chest X to the right-hand end of the cylinder C by means of the steam-port, or passage D. The space F in the diagram is the exhaust-port communicating with the atmosphere or the condenser as the case may be, through which the spent steam, which has already done its work at the other end of the cylinder, is allowed to escape by means of the steam-port D. When a sufficient supply of steam has been admitted to the end of the cylinder at C, and has forced the piston B to the other end of the cylinder, the position of the slide-valve J is changed, so that it not only closes the admission of steam to the end C of the cylinder, but it opens the steam-passage D to the high-pressure steam at the other end, and at the same time makes a communication between the passage X and the exhaust F, by which the spent steam escapes from C, and allows the piston B to be forced back again to C from the other end of the cylinder.

This reciprocal motion having been obtained, it is necessary to control and regulate it so that it may be turned to useful purposes. The most useful method of utilising the force is to convert the reciprocating into a rotary motion, whereby, with the aid of a belt or some kind of gearing, the motion may be communicated to any desired machine. The reciprocating motion is converted into rotary motion by means of a connecting-rod and crank.

The connecting-rod is jointed at one end to the piston-rod, P, fig. 325, which, we have seen, has a reciprocating motion imparted to it by the force of the steam acting on the piston, and at the other end it is attached to a crank, a species of handle familiar to all who have watched the working of a steam-engine. The reciprocating motion of the piston-rod is communicated through the connecting-rod to the crank-pin by alternate pulls

and pushes, causing it and the axle upon which it is fixed to rotate.

In order to prevent the intermittent motion due to the sudden action of the steam upon the piston, which would cause a jerky movement of the crank, a heavy fly-wheel is keyed upon the crank-shaft or axle. This wheel serves to steady and regulate the motion of the crank, and prevents the waste of power which would assuredly take place, even if it were possible to communicate the jerky motion of the piston direct to a machine. The fly-wheel is simply an accumulator storing up the energy imparted by the piston to the crank when exerting its utmost power, and imparting it to the shaft when the piston is exerting its smallest power. Thus, although the crank-shaft without a fly-wheel would rotate with a jerky and irregular motion, the movement when furnished with such a wheel is comparatively steady and uniform.

The engine must also be fitted with a suitable arrangement of gear to work the slide-valve, which is generally driven by an excentric keyed upon the engine-shaft, and so set with regard to the position of the piston in travelling backwards and forwards in the cylinder, as not only to open the steam passage for the admission of the high-pressure steam to do its work on the piston, but also to allow the steam which has already done its work to escape through the exhaust into the atmosphere or into the condenser.

The arrangement of steam-distribution here described is a very simple and fairly effective one. It is that which is used upon nine-tenths of the engines in ordinary use, and answers well for all practical purposes. It is not, however, by any means the most perfect or economical arrangement for the purpose, as there are many beautiful and efficient expansion arrangements in everyday use on the better class of large engines, for a description of which space cannot be spared here.

The object aimed at in all these arrangements is the same—viz., to obtain the advantage of the expansive action of the steam upon the piston. This can be fully realised only by suddenly admitting it with its full pressure into the cylinder when the piston is at the be-

ginning of its stroke, and cutting it off equally quickly when a sufficient quantity has been admitted to do the necessary work. The steam, being an expansive body, continues to exert a considerable though gradually diminishing force in the cylinder long after its further admission from the steam-chest to the cylinder has been arrested. It is by taking the fullest advantage of this expansive power that the greatest economy in working can be obtained.

Expansive Action of Steam in Single Engines.—In using steam expansively in a single-cylinder engine, there is a considerable loss caused by the cooling action of the expanded steam upon the inner surface of the cylinder. The temperature of steam is in exact proportion to its pressure, so that when high-pressure steam is admitted to a cylinder it possesses a correspondingly high temperature. But when it has been cut off early in the stroke, and has done its work by expansion until the moment of its release approaches, the pressure and corresponding temperature will have been greatly reduced. The metal of which the cylinder is composed is a fairly good conductor of heat, and the moment the hot high-pressure steam is admitted the temperature of the metal is immediately raised. But when this hot steam has become cooler by the reduction in temperature due to expansion, the cylinder (which has the same facility of parting with its heat which it has of absorbing it) is instantly cooled by imparting some of its heat to the cooling steam. The consequence is, that when the next supply of hot high-pressure steam comes in contact with the cooler surface of the cylinder, it is partially condensed, and its initial pressure and consequent force is considerably decreased.

Compound Engines.—To minimise this effect, recourse has been had to what is known as the “compound” system. This consists of making the engine with two or more cylinders. The first, and smallest, is that into which the high-pressure steam is primarily admitted. Here it is allowed to exert its full force upon a piston of comparatively small area for a considerable portion of its stroke, so that when the moment of its release arrives, the pressure and corre-

sponding temperature have not been greatly reduced by expansion. Consequently the inner surface of the cylinder has not been so much cooled as to cause any considerable condensation on the admission of the hot high-pressure steam for the next stroke. After having thus done a portion of its work in the first cylinder, the steam passes into a second one of larger diameter, where it further exerts its power at a lower initial pressure on a larger piston, in which it gives off its utmost expansive power before it is discharged into the air or into the condenser.

The advantage of compounding is thus obvious. It not only prevents a large measure of injurious condensation of valuable high-pressure steam by providing for its expansion in a second cylinder, but as the two cylinders involve the use of a double-throw crank-shaft, it distributes the strains on the working parts more evenly, and ensures steadier and smoother running than is generally obtainable with single-cylinder engines working with steam at high pressures.

In *compound* engines the cylinders are so proportioned that the small one working at the higher pressure gives off about the same amount of power as the larger one working at the lower pressure. This equalises the strain upon the crank-pins and other portions of the mechanism, and reduces the wear and tear and liability to breakages. By confining the action of the high-pressure steam to the comparatively limited area of the smaller piston, the violent and injurious shock at the beginning of each stroke is very much less than if the whole power of the steam had been utilised in a single cylinder of larger diameter, even although by expansion of the steam the total power given off should be the same in each case. Moreover, when a condenser is used, the effect of the vacuum is very much greater by acting upon the increased area of the larger piston, which, of course, is the one in communication with the condenser. In engines of large power the compound principle has been extended till three cylinders in a series are very common, and give excellent results; while four and six cylinders have been tried, with much success, for large marine engines.

Different Types of Engines.

Vertical Engines.—In the early days of steam on the farm, large independent vertical engines were generally used; but they are now, like their contemporary the egg-ended boiler, almost obsolete. Formerly, when all considerable powers were transmitted by spur-gearing, the vertical engine was used with advantage, as the height of the crank-shaft above the ground was convenient for the arrangement of the various wheels and pinions by which its power was to be given off. Now, however, all such powers as are likely to be required for driving any kind of agricultural machinery may be more easily, silently, and quite as effectively transmitted by belting, so that the height of the motive shaft is of no consequence, as in any case it simply means a few feet of belting more or less. Unless, therefore, there are other reasons to the contrary, no one would now choose an engine of the vertical construction for ordinary farm-work.

Horizontal Engines.—The horizontal engine is distinguished for convenience of fixing, accessibility for cleaning or repairs, and absence of vibration in running. It is therefore generally employed where the work is of a permanent nature. It consists of a strong cast-iron bed-plate, which may be bolted down to a brickwork or masonry foundation. This bed-plate forms a support for the cylinder, motion-bars, crank-shaft bearing, and condenser, if any. The joints of these various parts should all be planed, and fitted to facing-pieces cast solid with the bed-plate, which should also be planed true to receive them. They are then bolted firmly together with turned bolts, so that the thrust-and-pull of the piston does not cause any shake or vibration of the different parts. The crank-shaft, which bears at one end upon the plumb-block on the bed-plate, is supported at the other by a bearing fastened to a wall-box built into the engine-house wall. The fly-wheel is carried upon this shaft, as well as the excentrics for working the valves and pump.

In an ordinary farm-engine, which is required to revolve only in one direction, no provision is made for reversing gear, which, if necessary, could be attached by

the addition of another excentric and the ordinary link motion. The governors, which are a most important part of the engine, are generally driven by a belt from the crank-shaft. They may be made either to act upon a throttle-valve, which regulates the admission of steam to the steam-chest, or they may be made to act directly upon the slide-valve itself, controlling the period of admission of the steam to the cylinder. This latter is decidedly the best means of regulating the speed of an engine; because it will be seen, from the remarks already made upon the use of high-pressure steam, that to obtain the full benefit of expansion it should be admitted at full boiler-pressure to the cylinder, and then suddenly cut off. But where the governors act upon a throttle-valve, they exercise their function by reducing the initial pressure of steam admitted to the steam-chest (technically called *wiredrawing*); whereas, in the other case, the full boiler-pressure is admitted direct to the piston, and the power and speed are regulated by the period at which such admission is closed by the action of the governor upon the slide-valve.

When a condenser is not used, the exhaust-steam should be utilised for heating the boiler feed-water in a proper feed-heater before being carried by the waste-pipe through the roof or into the engine-chimney. When a condenser is used, the waste steam is conveyed to it by pipes, and is there condensed, as already described.

Horizontal Condensing Engine.—For engines of 20 horse-power and upwards, where sufficient space is available, and where the character of the work is permanent, the most convenient and economical plan is to put down a horizontal condensing engine, and a single- or double-flue "Cornish" or "Lancashire" type boiler to correspond.

Vertical Boiler and Engine.—For the smallest sizes of engine, say from 1 to 6 horse-power, where economy of space may be a great consideration, and where economy of fuel is not of great importance, the vertical boiler is frequently used in conjunction with a vertical engine with inverted cylinder working downwards on to a crank-shaft, as in

fig. 326, made by Marshall Sons & Co., Ltd., Gainsborough.

This type of engine and boiler is very convenient for dairy purposes and for food-preparation, chaff-cutting, grinding, &c.; but it is wasteful of fuel, as was shown at the trials of farm-engines at

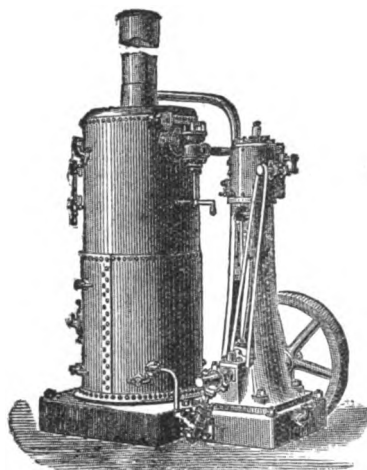


Fig. 326.—Vertical boiler and engine.

the Glasgow Show in July 1888, where one of these engines used more than three times as much fuel as the prize engine, which had a boiler of the locomotive multitubular type.

Portable Engines.—The portable engine (fig. 327), which has been employed to such a great extent for farm-work, is almost too well known to call for any description. It has stood the test of 50 years' steady work, during which time it has developed to the almost perfect machine which it now undoubtedly is. The boiler is of the locomotive type, covered with wood and sheet-iron to prevent radiation of heat. The fire-box should be large, not only for the purpose of giving a large area of available heating-surface, but also to give sufficient grate-area to burn the necessary amount of fuel without forcing and consequent waste. The tubes are generally made of iron fitted at both ends to the tube-plates, which have been bored out to receive them, expanded in position with tube-expanders, and protected from the fire by steel ferrules. All fire-boxes ought to be provided with a lead safety-

plug, which, when the level of the water in the boiler gets dangerously low, is melted, the fire being thus put out. The cylinder ought to be steam-jacketed, and all the various covers so arranged that they can be easily and quickly removed for examination of the various working parts, without the necessity of blowing off the steam. The portable engine illustrated is that made by Clayton & Shuttleworth, Ltd., Lincoln.

The crank-shaft is invariably bent out of a single solid round bar, so that the fibre of the iron or steel is always in the best position to resist the strain, and con-

sequently the chances of breakage are reduced to a minimum. The crank-shaft brackets are generally made of wrought-iron riveted to the barrel of the boiler, and carry the journals or bearings in which the crank-shaft revolves. These ought to be made of phosphor-bronze, as it has a much greater wearing power than even the best gun-metal. The slide-bars, slide-rods, &c., should all be made of the best iron, case-hardened, otherwise the wear and tear and consequent deterioration will be very rapid and great.

The excentric should be so arranged that, in case of need, it can in a few

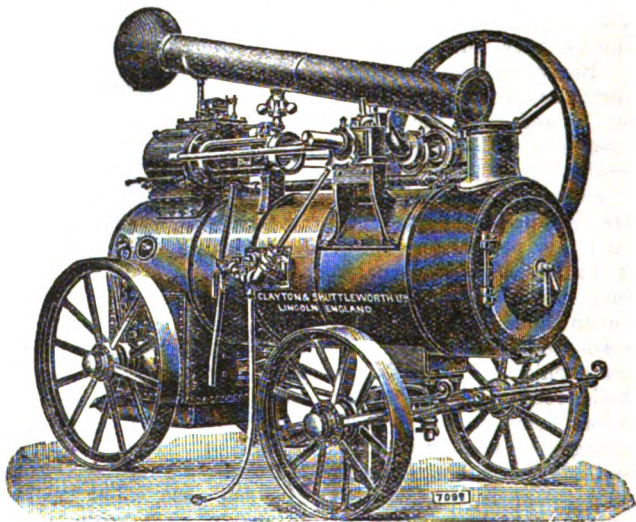


Fig. 327.—Portable steam-engine.

moments be set so that the engine will work in either direction. This can be done without trouble by making the excentric loose upon the crank-shaft, and keying the circular disc alongside of it securely to the shaft. This disc has two holes, by one of which the excentric may be bolted for the forward gear, and by the other for the backward gear.

It is a matter of necessity that each engine should be fitted with two safety-valves, one at least being in a locked-up iron casing, so that it cannot be tampered with by the attendant. They should also have a steam jet for drawing the fire quickly when raising steam; a man-hole and cover for convenience of cleaning, examining, and repairing the

boiler; and mud-holes for washing-out purposes.

The engines are generally provided with a waterproof cover, so that they may be left out in the rick-yard or in the field in all weathers. They are also fitted with a drag-shoe, for use when going down steep hills. In very hilly countries the engine is also fitted with a screw-brake for this purpose.

Semi-portable Engine.—What is known as the semi-portable or semi-fixed type of engine is one which has enjoyed a large share of public favour for many years. There are two descriptions of this class of engine—one in which the cylinders and working parts are bolted on the top of the boiler, and the

other in which the working parts are erected upon a foundation-plate, and placed underneath the barrel of the boiler, as shown in fig. 328. Both these types of engine have their special advantages. The former combines lightness of weight and fewness of parts with a ready accessibility for overhauling, examination, and repairs, and is very suitable for all purposes where powers say up to 20-horse nominal are required. The description of this engine practically corresponds with that of the ordinary portable, with the exception of the wheels, which are taken off, and in their

place are substituted a cast-iron ash-pan underneath the fire-box, fitted with a draught-regulating door; and a pillar of cast-iron or brickwork, which is placed underneath the perch-bracket at the front end of the boiler. The type of semi-fixed engine with working parts underneath the boiler as illustrated is very convenient for powers varying from 10 to 50 nominal horse.

Many of our leading engineers have brought great skill in design and excellence of workmanship to bear upon the construction of these engines, until they have attained a perfection of working

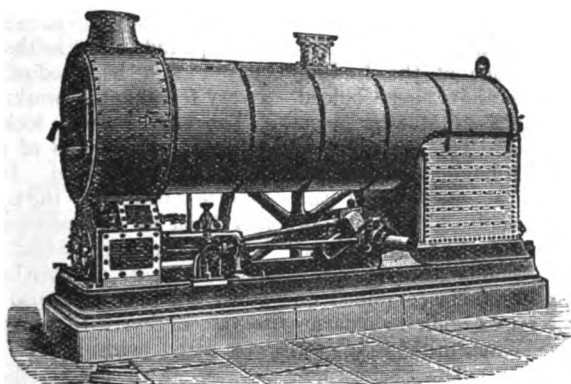


Fig. 328.—Semi-fixed engine and boiler combined.

which can scarcely be equalled, and has never been excelled, in any other type of steam-engine. It may be interesting as a historical fact to record that the first engine of this type was constructed early in the latter half of the last century by Manning, Wardle, & Co., the well-known locomotive engineers of Leeds, from the designs of their manager, the late Mr Robert M'Intyre.

Amongst the great advantages possessed by this class of engine may be named the following: Expensive foundations are dispensed with, as the engine can be set so as to work steadily and well merely fixed upon two baulks of timber; economy of space, inasmuch as both engine and boiler can be fixed in the room which would be necessary for either one or the other if they were fixed separately; and facility for removal if required, as it can be lifted bodily on a trolley, or mounted on a set of temporary wheels and axles, by which it can be moved from

place to place. No brick chimney is required, as the wrought-iron chimney, which should be sent out with each engine, in conjunction with the blast caused by the exhaust-steam, is sufficient to give the necessary draught for the perfect combustion of the fuel. The larger powers of these engines are generally made on the compound principle, which has been already described.

Where economy is a desideratum, these, like all other steam-engines, should be fitted with the best automatic expansion arrangements and condensers, so as to economise to the utmost the consumption of steam, and consequent expenditure of coal and water. The locomotive type of boiler, which is a most economical steam-generator, combined with perfect-expansion gear, and proper proportion of the various working parts, whereby the loss from friction and other causes is reduced to a minimum, unite to make this class of engine one of the most suit-

able and popular forms for use in agriculture.

Simplicity in Engines.—In all kinds of machinery simplicity of construction is of the utmost importance, and in cases where economy can be attained only at the cost of simplicity, it may be advisable to sacrifice somewhat of the former in order to make sure of the latter. It must be borne in mind that agricultural steam-engines are often put into the hands of men unskilled in the management of machinery, and sometimes very careless and negligent in the use of the expensive apparatus which they are called upon to direct. The advantages of simplicity are therefore obvious.

Highland and Agricultural Society's Trials.—None of the leading agricultural societies have held official trials of steam-engines suitable for farm-work for many years. The last trials of any importance were held at Glasgow in July 1888, under the auspices of the Highland and Agricultural Society of Scotland. A prize of £75 was offered for the best fixed steam-engine of 6-horse-power nominal, with boiler combined or separate, suitable for erection in a farm-steading, the price being limited to £150, delivered at Glasgow. The Society decided to award the prize to the engine which embodied in the highest degree the following points of merit of the relative value stated:—

	Points.
Price	20
Simplicity of construction and fewness of working parts	25
Economy of fuel	20
Rapidity of raising steam	5
Facility of erection and cheapness of foundations	5
Economy of water	5
Steadiness and regularity in running	15
Economy of lubricant	5
Total	100

Four engines were tried on the brake, and the results of the trial were such as to demonstrate the imprudence of purchasing any class of engine merely because it happens to be offered at a low price. Between the lowest and the highest price the difference did not amount to more than £35, or thereby; while as to economy of working, the result was out of all proportion.

The prize was awarded to J. & H. M'Laren, Midland Engine Works, Leeds, for a 6-horse-power nominal engine and boiler combined, which, during the trial, worked at 14 actual or brake horse-power, with a consumption of 4.13 lb. of Scotch coal per brake horse-power per hour, and a water consumption of 33.97 lb. per brake horse-power per hour. The engine which did worst in the trial consumed 13.63 lb. of coal and 63.79 lb. of water for every brake horse-power given off, which means that the one engine would use £10 worth of coal to do a certain amount of work for which the other engine would require over £30 worth,—showing clearly that a few pounds extra in the first cost of an engine might be saved off the coal-bill in a very few months' working.

The engine which took the prize was mounted on the top of the boiler with which it is combined. It can, however, be lifted bodily off the top of the boiler and fixed as an ordinary self-contained horizontal engine, so that it can be placed inside the barn or other building, and the boiler put in an outhouse and coupled up to the engine with pipes. This engine was fitted with a very efficient feed-heater, which heated the water nearly up to boiling-point before it entered the boiler, which, of course, effects a great saving of fuel.

Traction-engine.—Traction-engines such as that shown in fig. 329, made by J. & H. M'Laren, Leeds, are now largely used in agricultural operations, although not yet to the same extent as the portable engine. The reasons for this are probably because it costs about twice as much as a portable engine of equal power; that there are many legislative restrictions imposed upon their use on public roads; and that, until comparatively recently, they were made so clumsy and heavy that they were difficult to manipulate. Now, however, that steel-casting has been brought to such great perfection, the spur-gearing is invariably made of that material, which gives much greater strength with very much less weight. Additional experience has also enabled the makers of traction-engines to simplify their construction to such an extent that they are not only very much lighter, but less cumbersome in appearance and more

easy to handle. Indeed they have long passed the experimental stage, and are rapidly superseding the portable engine for driving travelling threshing-machines.

Traction-engines have the great advantage not only of moving themselves from farm to farm, but also of hauling their machine and straw-elevator with them, so saving the user the trouble and risk attendant upon moving these heavy articles by horses. The locomotive type of boiler is almost invariably adopted for traction-engines, and as the working steam-pressure is generally from 120 to 180 lb. on the square inch, it requires to be made of the very best materials, and put together in the strongest possible way. They should be able to stand a test-pressure, by cold water, of 300 lb.

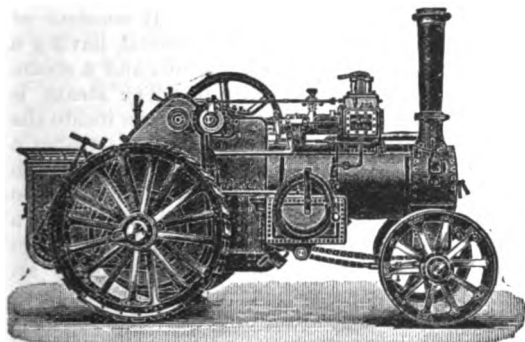


Fig. 329.—Agricultural locomotive or traction-engine.

on the square inch without showing any signs of weakness.

The power of the traction-engine is conveyed from the crank-shaft to the travelling-wheels by means of spur-gearing, which ought to be of the best quality of cast-steel. It is a great advantage for the engine to be fitted with double speed to the road motion, the slow gear causing it to travel at the rate of two miles per hour, and the fast speed at four miles per hour. The advantage of this arrangement is, that when the engine is travelling on level roads with a good load, it can maintain the higher rate of speed, but might not be able to do so if it should be necessary to mount a stiff hill. In that case, however, the slower and more powerful speed can be thrown into gear, thus giving the engine a greater "purchase" or leverage, and enabling it

to mount the hill without distress. Recently it has become usual to fit these engines with a third speed, so that when travelling on good roads with empty waggons or a light load the engine can travel at a speed of six miles per hour.

The variation of the speed is accomplished by means of pinions of different size sliding upon squares on the crank-shaft. One or other of these pinions, as the case may be, gears into its respective speed wheel fixed on the second motion shaft. These speed wheels consist of spur-wheels of different diameters of such a size that, when the smaller crank-shaft pinion is thrown into gear, it works in contact with the larger of the wheels, imparting a slow motion to the engine; and when the larger pinion on the crank-shaft is thrown over into gear, it communicates the motion to the smaller of the speed wheels, thus increasing the rate at which the engine will travel.

When it is desired to change the speed, it is only necessary to stop the engine for a moment, and by simply moving a lever, either pinion may be thrown out and the other thrown into gear; or they may both be thrown out of gear, when the engine will remain stationary, and may be used for driving any description of machinery by means of a belt from the fly-wheel.

For guiding the engine when travelling upon the road, it is necessary that it should be fitted with some description of steerage. This generally consists of a shaft across the front of the fire-box shell, underneath the barrel of the boiler, having upon one end a worm-wheel. This worm-wheel is worked by a worm on the end of a shaft, which is carried back to the place where the driver stands. This shaft has, at the opposite end to the worm, a hand-wheel, by means of which the driver, by a very slight effort, can turn it either way, thus causing the steerage shaft to revolve in whatever direction may be required. By connecting-chains from this steerage-shaft to the front axle, the front wheels may be drawn into either lock, so that when the engine is in motion it can be guided either to the right hand or to the left,

and will turn a very acute angle, or in a very small circle.

In order to facilitate turning sharp curves, what is known as a differential gear has been applied on the main axle of these engines. This consists of a pair of bevel-wheels face to face, the one keyed firmly upon the axle, the other keyed or otherwise secured to one of the driving-wheels, which is loose upon the axle. There are two bevel-pinions fixed upon pins or studs, and carried between and in contact with the two aforesaid bevel-wheels.

The power of the traction-engine is communicated through these bevel-pinions to the bevel-wheels in such a way that either of the road-travelling wheels may move a little quicker than the other without surging or waste of power. Thus, in turning sharp curves, the inner wheel may travel slowly, and the outer wheel may travel quicker, having the greater distance to move. This complicated motion was invented about 1850 for use in cotton-spinning, and is now employed largely, not only on traction-engines, but for vehicles, such as motor-cars, tricycles, &c., which have to work under similar conditions. The arrangement relieves the axle of a large amount of strain which would otherwise be caused by the inner wheel slipping, and when necessary it can be so locked that both wheels will revolve with the axle. This is of great service when the engine is sunk in a soft place, and all the power is required to be applied on one side to lift it out.

Every traction-engine should be fitted with a winding-drum fixed on the main axle, containing about 50 yards of steel rope. By throwing the road-wheels out of gear, and putting the winding-drum in motion, the rope may be used for a great variety of useful purposes. For instance, in soft stack-yards the engine may be moved on to the hard road after work has been finished, and the threshing-machine drawn up to it by the rope, thus avoiding cutting up the ground by the shunting necessary to couple up the engine direct to the machine. The machine or traction-waggon may also be drawn out of awkward places, where it would not be practicable or convenient to take the engine. For road-

work the drum is also extremely useful, as a much larger load can be attached to the engine; and in the event of a steep hill having to be encountered, the engine may be detached and taken to the top, then the rope can be unwound and secured to the load, and the latter drawn up and coupled to the engine again. The rope may also be used for hauling timber out of plantations, pulling up roots of trees or the stumps of hedges, or, by being passed over a pulley, it can be used for loading timber, &c. The drum should revolve loosely on its own axis, so that it can pay off the rope while the engine itself is travelling forward into position.

These traction-engines should also be furnished with a water-lifter, which is a little instrument on the same principle as the Giffard Injector. It consists of a small outer casing of metal, having a water inlet pipe on one side and a steam inlet pipe on the top. The steam is blown through a conical nozzle inside the instrument, and in its passage creates a vacuum, which sucks the water through the inlet and throws it forward into the tank. It is generally fitted with a length of india-rubber suction-hose, so that in a few minutes the tank of an engine can be filled with water from any convenient brook or pond. This not only saves a great deal of time and manual labour in filling the tank with water, but it ensures the water being delivered into the tank, and consequently into the boiler, in a much cleaner state than where buckets are used for filling the tank. It can also be used in very shallow places where there is only sufficient water to cover the nozzle on the end of the suction-pipe, and where any attempt to lift the water with buckets would stir up the sediment, and lead to a great deal of dirt and grit being deposited in the tank, which would eventually find its way into the boiler.

Traction-engines can be employed for driving every class of machinery used on the farm, such as for threshing, steam-cultivation, &c., and also for hauling the produce of the farm to the nearest town or railway station, and bringing back manure, feeding-stuffs, lime, &c.

They are also used by contractors for

threshing, who drag the machine about with them from place to place, and thus do away with a great deal of hard work which formerly used to be very trying to the horses. When used principally for road-haulage, they should be fitted with an extra tank under the barrel of the boiler, so that a larger store of water may be carried on the engine and frequent stoppages to take in a fresh supply may be avoided. For agricultural purposes single-cylinder engines are usually employed, but where there is a considerable amount of road-travelling to be done, the compound system is recommended.

STEAM-CULTIVATION.

One of the most important and interesting uses to which steam has been applied is that of the cultivation of the soil. Forty years ago, when the price of corn was fairly remunerative, a large amount of land which has now been laid down to grass was under the plough. Farmers had more capital to spend on machinery, and the earlier agricultural engineers—Savory, Fowlers, Howards, Amies & Barford, Smith of Woolston, Fiskin, and others—competed for their orders and patronage. Many most ingenious systems were introduced, all more or less complicated, but of these practically only one has survived—i.e., the double-engine system, which is described later on, along with one of the best roundabout systems which is still occasionally used. By the use of steam the land may be drained, ploughed, grubbed (or cultivated), harrowed, and rolled, much more expeditiously than would be possible with the ordinary number of horses usually kept upon the farm. The owner of a steam-plough tackle is therefore in a position to take full advantage of any brief intervals of suitable weather which may occur in an otherwise unfavourable season, for the preparation of his land and getting in his crop. The greatest advantage of the steam-plough is obtained in dealing with strong land, where a large amount of working is required to bring it into condition for sowing.

Injury by too deep Ploughing.—At the same time, the power which is available for tearing up the soil requires

to be judiciously exercised, as many British farmers have found to their cost. When the steam-plough was introduced, some seemed to expect that it would revolutionise agriculture, and many farmers, unaware of, or neglecting, the real principles of cultivation, had their land ploughed to the utmost depth of which the tackle was capable. In rich loamy lands where there was a sufficient depth of fertile soil, this was no doubt attended with advantageous results. But in shallower soils and strong clay lands, where the ground had been cultivated by horse-power to the full depth of its fertility, the consequences were most disastrous. In such cases the injudiciously deep ploughing amounted to nothing short of burying what little good soil there was under a deep layer of cold sour stuff, which it took years of expensive working and manuring to bring into fertile condition.

Prejudice against Steam-ploughing.—This circumstance naturally aroused considerable prejudice against steam-ploughing, and now one often hears farmers state that they would not employ a steam-plough on any account, adding that, long ago, they had a field entirely spoilt by it. But in most cases it will be found that the blame is not due to the steam-plough itself, but to the imprudent manner in which it had been employed.

It used also to be claimed for the steam-plough that by its use the land could be cultivated at all times and in any condition. No doubt the mechanical operation of stirring or turning over the soil could be done at any season, and in any condition; but the mere fact of cultivating land by steam instead of by horses makes no difference in the effect of the cultivation. If a certain class of soil, say a strong clay, cannot, without disadvantage, be ploughed by horses, it cannot advantageously have the same operation performed upon it by steam.

Complaints have also been urged against the steam-plough on account of the weight of the engines disturbing and deranging the drains. These complaints may be well or ill founded, according to the depths of the drains, the state of the ground when the steam-plough is used, the suitability of the tackle for the ground on

which it is to be used, and the expertness or clumsiness of those who have charge of it.

Advantages of Steam-ploughing.—When the steam-plough is judiciously used, its employment is attended with the utmost advantage to the farmer. By its means large areas of land can be quickly and cheaply prepared for the seed. The moment the first of the cereals are cleared from the land, the steam-plough can and should be set to work, the horse-power of the farm having still some weeks' work to do in completing the saving of the harvest. It enables the number of horses necessary for a large farm to be considerably reduced, thus effecting an important saving in forage and wages. It can also be used to break up the subsoil, so as to greatly assist the drainage, and allow the roots of the plants to penetrate deeper into the earth.

The changes made in this respect in certain lands in which there was a "pan" underneath the soil are very remarkable. In land on which the water used to stand for days after a heavy rainfall, before the steam-plough was used, it now gets so freely away that after a few hours no water can be seen, even though it may have rained heavily for several days. This breaking up of the subsoil can be accomplished by means of the steam-grubber or cultivator, without having the injurious subsoil brought to the surface.

The following are the different systems of steam-cultivation :—

Double-engine System.

For large occupations, or for letting out on hire, the double-engine system is no doubt the best, owing to the ease and rapidity with which it can be moved from field to field and set to work ; to the

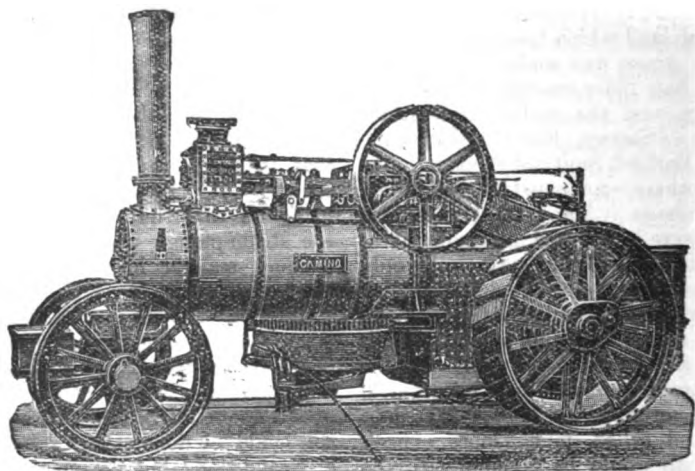


Fig. 330.—*Ploughing engine.*

large area of land which can be cultivated, owing to the economy of time in shifting ; and to the large percentage of power brought to bear upon the implements, which may be much broader in proportion for this than for any other system.

The tackle consists of a pair of traction-engines, such as that shown in fig. 330, made by J. & H. McLaren, Leeds. They are fitted with winding-drums underneath the barrel of the boiler, worked by bevel-gearing from the crank-shaft,

each drum containing from 400 to 500 yards of specially strong steel-wire rope. The engines are placed on opposite headlands of the field to be cultivated, as shown in the engraving, fig. 331, p. 424, and they work alternately—the one hauling the implement across the field, while the other is paying out the tail-rope and moving forward into position for the next "round."

The whole power of the engine can thus be directly applied to the implement by means of the wire rope. This rope is

evenly coiled upon the drum by means of coiling-pulleys, which swing upon an arm on the same centre as the drum, so that they accommodate themselves to any angle at which the rope may be working, and which move up and down automatically as may be required for the "lay" of the rope.

Steam-plough Engines.—Like the traction-engines already described, the steam-plough engines should be fitted throughout with cast-steel spur-gearing for the road motion, and double speed for travelling on the road. The spur-gear for the ploughing motion should also be of steel. Steel axles and shafts should also be used, as they are not only stronger than iron but much stiffer, and consequently not so liable to bend. The road-travelling wheels should be of extra width to prevent sinking in soft land. The engines should be fitted with an injector, as well as a pump, for feeding the boiler. A water-lifter with india-rubber suction-hose should be fixed in the tank for replenishing it with water; and as a pretty large stock of spare tools

and duplicates are generally carried with each engine, a tool-box of large capacity is generally fixed upon the front axle.

Cost of Steam-ploughing Plant.—

The most convenient size of steam-ploughing engines for very large holdings, and for letting out on hire, is about 14 horse-power nominal. These will haul a 6-furrow plough with ease, turning over from 14 to 16 acres for a good day's work, or an 11-tined turning cultivator, tearing up and loosening the soil to a depth of from 7 to 9 inches, to the extent of about 25 acres for an average day's work. The cost of the complete plant, consisting of the two engines (with 400 yards of steel rope on each), 6-furrow plough, with steel skifes, 11-tined turning cultivator, and 6-framed flat reversible harrow, amounts to about £2000. Assuming the owner of such a set of tackle to have sufficient employment for it, the amount of work done by it, and the net cost price to the proprietor, would be about as follows, assuming the tackle to work 120 days in the year:—

Cost of working steam-plough for season of 120 days.

<i>Dr.</i>		
By interest on £2000 capital expenditure at 5 per cent per annum	£100	0 0
" depreciation, wear and tear, repairs, renewals, and redemption of capital, say 10 per cent per annum	200	0 0
" 2 enginemen at 5s. each, and 1 ploughman at 4s. per day	£0	14 0
" 1 man and horse leading water to engines, per day	0	7 6
" coal for two engines per day, and leading (say)	0	16 0
" oil, waste, stores, &c.	0	4 6
Total wages per day	£2	2 0
Making for 120 days	252	0 0
Total annual expenses	£552	0 0
<i>Cr.</i>		
To 40 days' ploughing, 15 acres per day = 600 acres, at 6s. 6d.	£195	0 0
" 60 " cultivating, 25 acres per day (once over) = 1500 acres, at 3s. 6d.	262	10 0
" 20 " harrowing, 40 acres per day (once over) = 800 at 2s. 4½d.	95	0 0
	£552	10 0

This leaves a balance of 10s. in favour of the tackle, after doing the work at the extremely low net cost price of 6s. 6d. per acre for ploughing, 3s. 6d. per acre for cultivating, and 2s. 4½d. per acre for harrowing. The cost per acre would be greatly reduced by keeping the tackle at work for a longer period, as the chief items of expense—interest and depreciation—remain the

same whether the machinery works 120 or 220 days in the year. The cost of hiring steam-ploughing tackle from contractors for the same work, exclusive of the cost of fuel and leading, coal and water, which are borne by the customer, would be about as follows:—

Ploughing—8 inches deep	10s. 6d. per acre.
Cultivating twice over	12s. od. „
Harrowing twice over	6s. od. „

These prices are based on the standard of fair medium loamy soils. For stiff clays or specially hard or stony ground, of course they would not apply, the prices in these cases depending entirely upon the governing circumstances.

Tackle for 1000 Acres.—For holdings of about 1000 acres, a pair of 12 nominal horse-power ploughing-engines would probably be the most convenient size. They will haul a 5-furrow balance-plough, or a 9-tined turning cultivator, doing from 10 to 15 acres of ploughing, and from 15 to 20 acres of cultivating, per day.

The cost of this tackle, including the two engines, with 400 yards of rope on

each, 5-furrow balance-plough with steel skifes, 9-tined turning cultivator, and 5-framed flat reversible harrow, is about £1750.

The smaller size of tackle has the advantage that the engines are more convenient for road-haulage, threshing, &c. With a little trouble the ploughing-drums can be detached, and the engines correspondingly lightened, when they can be used for most of the purposes of ordinary agricultural locomotives, for which the stronger engines are too heavy and unwieldy.

All the different sizes can, however, be used for the ordinary work of the farm—such as driving threshing, grinding,

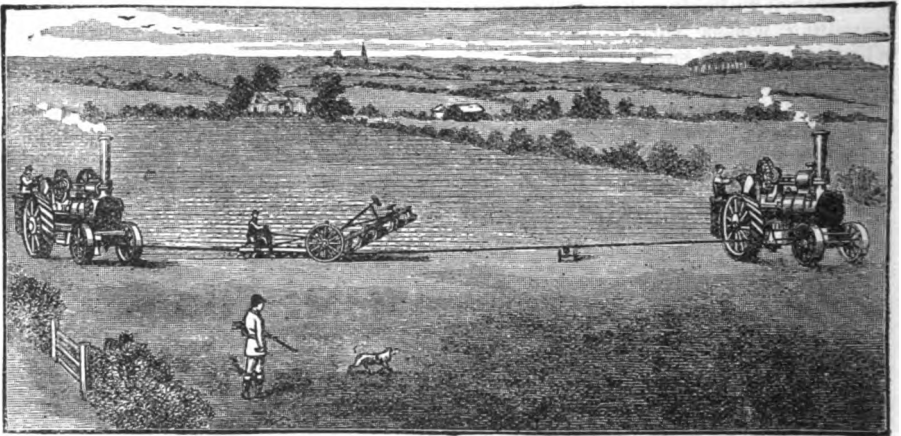


Fig. 331.—Double-engine steam-plough.

sawing, or other machinery—by means of a belt from the fly-wheel. At an extra cost the engines can be made compound, which is a great advantage, owing to the economy of coal and water thereby secured, equal in practice to about 25 per cent. The engines can also be fitted with a double speed for the drum. This is an important improvement, as by its use the slower and more powerful speed can be used in stiff land or when doing deep work, and the fast speed can be employed for light work, such as harrowing or cultivating the second time over, when the same power is not required, but the whole strength of the engine can be utilised by driving the implement at a higher speed, and thus getting over a much larger area of ground per day.

Single-engine Systems.

There are various systems of steam-ploughing tackle before the public for working with one engine only. The most successful appear to be those manufactured by Barford & Perkins of Peterborough. They may be divided into two classes: (1) That in which the implements are worked by ropes from a self-moving engine having double drums mounted upon it; and (2) That in which the implements are worked by ropes from a portable windlass, carrying the two drums, which are driven by means of a pitch-chain or universal coupling from the crank-shaft of an ordinary traction or portable engine.

The former system (No. 1), as illus-

trated in fig. 332, consists of a traction-engine carrying two winding-drums, one on each side of the tender. These drums are driven direct from the road driving-gear of the traction-engine, the travelling wheels being thrown out of gear while the engine is required for ploughing. The drums each contain about 900 yards of steel rope—sufficient to set round a field of about 20 acres. They are fitted with automatic brakes, which fly off of their own accord when the drum is winding-up the rope (*i.e.*, hauling the implement), and drop into contact when the motion is reversed and the drum begins to pay out the tail-rope. The drums are

mounted upon excentric studs, and can be easily thrown in and out of gear by levers under the control of the engine-driver.

The tackle used in connection with this engine consists of certain snatch-blocks with claw-anchors, two self-acting travelling anchors, sundry steel-rope porters, and the implement, plough, cultivator, or harrow, as the case may be.

The self-moving anchors consist of a strong guiding-pulley carried on a suitable wrought-iron or wood frame. This frame, when the anchor is in use, travels on 4 sharp disc-wheels, which sink into the ground, and prevent the anchor pulling

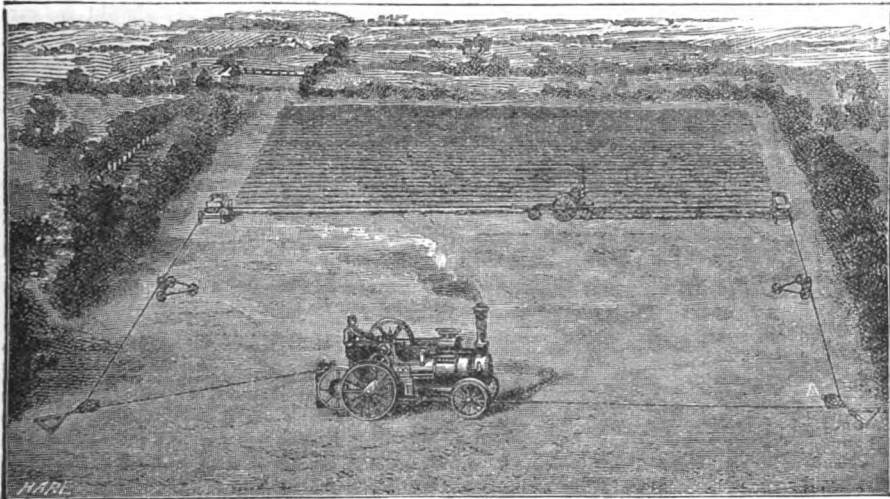


Fig. 332.—Single-engine steam-plough.

sideways with the strain of the rope. In order to press these discs well into the ground and prevent it tipping over, the anchor is generally weighted with stones, or other heavy material, carried in a box fixed on it for the purpose.

The front axle is provided with a simple form of steerage, which enables the anchor to be guided along uneven and crooked headlands. The hind axle, which revolves when travelling, is fitted with a series of 4 sets of claw-tines which are fixed thereto and revolve with the axle. This axle also carries a pawl-wheel, which can be locked and unlocked by means of a pawl-lever. This lever can be worked by hand, or it can be controlled automatically by the

steel rope. In the latter case, a ball is fixed on the steel rope a few yards in advance of the implement. When the implement approaches the headland, this ball strikes a forked lever turning on the same centre as the guide-pulley. This forked lever raises the pawl-lever out of gear, and the forward strain on the steel rope causes the anchor to advance as far as may be required for the next round. The movement of the engine is then reversed, and the pulling rope now becomes the tail-rope, causing the implement to travel in the opposite direction.

As the implement begins to travel in the opposite direction, the pawl-lever again drops into gear with the pawl-

wheel and locks it, causing the claw-tines (which have revolved harmlessly with the forward motion of the anchor) to take a firm hold in the ground like the claws of a claw-anchor, so that when the tension again comes round the self-moving anchor in question, it cannot pull forward till the pawl-catch is again liberated.

An accident through the plough being pulled into the self-moving anchor is manifestly impossible, as the ball on the steel rope liberates the anchor before the plough can reach it; and the worst consequences of any neglect on the part of the engine-driver to stop the engine would be that the anchor would be hauled too far along the headland, with the plough following a yard or two behind.

The mode of working this system will be easily understood by a reference to the drawing, fig. 332. The engine is placed in a convenient position at one end or side of the field. The steel rope is taken off one drum and led out in front of the engine, and round a fixed snatch-block pulley secured by a claw-anchor in one corner of the field. It is then led at right angles down the side of the field to the far corner, where the self-moving anchor is fixed. Round the pulley of this anchor the rope is led, and attached to the implement.

The other steel rope on the other drum is led out behind the engine and round the other side of the field in a similar manner, and attached to the implement. The implement is then drawn to and fro between the self-moving anchors, which gradually move forward the width of the implement at each round till the whole of the field has been cultivated. The position of the engine and the anchors, &c., can then be changed, and the land can be cultivated or ploughed crosswise if required.

The cost of a complete set of tackle for working on this system, including an 8-horse-power double-drum traction-engine, 1800 yards of steel rope, necessary anchors and snatch-blocks, four-furrow plough, and 7-tined turning cultivator, is about £1000. The advantages it possesses over other sets of single-engine tackle, are,—fewness of parts composing the tackle, facility of setting to work

(the engine is set the moment it is steamed to its place), small number of hands required to work it—two men only, one for the engine and the other for the implement.

The engine has also the great advantage of being much lighter than any other double-drum engine, owing to the drums being driven off the road-gearing instead of by heavy independent shafts and gearing. The drums can also be dismounted in an hour or two at the end of the ploughing season, and the engine, relieved of all extra weight, can then be used without encumbrance as an ordinary farm traction-engine.

In order to prevent excessive wear and tear upon the ropes, they should be carried on rope-porter pulleys, placed at such intervals as will prevent the ropes trailing on the ground, which is very injurious to them, especially in sharp gritty soils. In such land it will pay to keep an additional hand to attend to these porters, taking them out in front of the advancing implement, and putting them in again after it has passed.

Barford & Perkins's No. 2 system is identical in its operation with the system just described, the only difference being in the application of the motive power (see fig. 333). This system has the great advantage that it can be worked by an ordinary portable engine. The winding-drums are carried on a separate windlass, which is dragged into position by horses. The power is conveyed from the engine to the windlass by means of a pitch-chain, and the drums are worked by spur-gearing from the main driving-shaft. They are fitted with brakes for paying out the steel rope, and, as in the former case, one drum is winding on or pulling up the implement, while the other is unwinding or paying out the tail-rope. The mode of working will be easily understood by a reference to the engraving (fig. 333).

The price of a set of tackle of this description, with windlass, 1800 yards of steel rope, 5-tined turning cultivator, and necessary appurtenances, but exclusive of engine, is about £360. This set has therefore the advantage of being comparatively cheap, and can be worked at small expense, only two men being absolutely necessary to work it. There

is, however, a good deal more tackle to be moved into position by horses, and considerably more time required for fixing and getting ready for work. Nevertheless many hundreds of such sets have been sold for farmers' own use; and on small occupations, or where the land is not too strong, their use has been attended with great advantage.

STEAM-DIGGING.

No notes on the subject of steam-cultivation would be complete without some reference to the steam-digger, invented

by Mr T. C. Darby of Pleshey Lodge, Chelmsford. It is to be regretted that the commercial success of this clever invention has not been such as to ensure its more general application. Mr Darby's attention was turned to the provision of an effective mechanical substitute for spade-cultivation.

The benefits of digging the soil as against ploughing it must be evident to all who are familiar with these two modes of cultivation, and who have carefully considered the subject. Apart from the waste of power in drawing a plough through the ground as compared



Fig. 333.—Single engine and windlass steam-plough.

with that required for turning over the same depth of soil by means of digging-forks, the quality of the work done in the latter case is much superior to that of the former. The ground is more perfectly pulverised, and left in a better form for the action of the atmosphere; while, owing to the "lifting" action of the clod, which is raised and turned over by the motion of the digging-forks, the subsoil is left more open for the escape of surface-water and the penetration of the roots of the plants. This action leaves no "pan"; but as the spit of earth about to be turned over has been torn, as it were, from the subsoil on which it rested, and to which it adhered, the subsoil is partly shaken up and loosened with the most beneficial effect.

Weeds killed by Digging.—The late Mr John Algernon Clarke gave a very

rational explanation of the curious fact of the comparative absence of weeds on land broken up by the digger. In examining work which had been done by this machine, he observed that the fork, lifting the spits of earth, drew out most of the long roots of the weeds from the subsoil, and threw them over to the action of the sun, which withered and killed them, and as the roots were not left in the ground they could not spring up again. On the other hand, the plough in cutting through the ground at a certain depth merely turned over those weeds whose roots did not penetrate below the sole or pan of the furrow, and cut in two the roots which went lower than this, leaving the ends in the ground ready to spring forth again at the first opportunity.

It is matter for regret that the great

Agricultural Societies, especially the Royal of England, give so little encouragement to the makers of agricultural machinery. The amount distributed in recent years in prizes to implement-makers is but a fraction of that distributed to the exhibitors of stock, and the consequence is, that for many years no marked improvement has been made in agricultural machinery. Farmers are reluctant to purchase new machines until they have been well tested, and it is a duty the societies owe to their members to encourage the invention of useful implements, and by official tests to ascertain their capabilities, so that their members may be guided what machines to select and warned what to avoid. But for their remissness in this respect, many useful farm-implements which have never got beyond the experimental stage would have been perfected, and machinery would have been made practically available for many operations of the farm which are still done only by animal power.

GAS- AND OIL-ENGINES.

Since about the year 1880 gas- and oil-engines have, to a considerable extent, superseded steam for driving farm machinery. Wherever the power required is comparatively small, such as for threshing, driving dairy machinery, &c., these internal combustion engines, as they are called, have many advantages over the older established steam-engines.

The Working of Gas-engines.—The gas-engine differs from the steam-engine inasmuch as the power, instead of being procured from steam admitted alternately to different sides of the piston, is obtained by the explosion of gas and air, mixed in certain proportions, acting on one side of the piston only. In a steam-engine there is an impulse given to the piston every stroke, both outwards and inwards—two impulses to one revolution of the crank. In the gas-engine there is only one impulse given every fourth stroke—that is, to two revolutions of the crank. In a steam-engine there is a “push-and-pull” effort on the crank-pin every revolution, but in the gas-engine there is only one “push” every second revolution.

When the mixture of gas and air is exploded in the cylinder of a gas-engine, the piston is forced outwards, and by means of a connecting-rod it imparts a rotary motion to the crank, as in the case of a steam-engine. But in a gas-engine, as already stated, the power is imparted to the crank on its outward stroke only, and the piston is pushed back into position for the next impulse by the momentum of the fly-wheel acting through the crank. In other words, the impulse of the explosion within the cylinder must give the crank a sufficiently strong push on the outward stroke to cause the fly-wheel to revolve with sufficient force or momentum to thrust the piston back to the inner end of the cylinder, where it receives another forward impulse from the next explosion. When the engine has been started and runs up to its proper speed, the fly-wheel has acquired a sufficient momentum, not only to steady the engine under the sudden shocks of each succeeding explosion, but to give off so much of its stored energy as may be required to overcome the resistance of the machinery which is to be driven.

It was in the seventh decade of the nineteenth century that Dr Otto, the celebrated German inventor, took out his patent for the first commercially successful gas-engine. Since that time enormous numbers of these engines have been made, and are working successfully in every field of industry. For a long time their use was limited to the smaller powers, but in recent years the sizes have been greatly increased, and gas-engines of 500 horse-power and upwards are now not uncommon.

Phenomena in the Working of the Otto Gas-engine.—In the Otto system, which has been adopted by practically all the English makers, the separate explosions or impulses are given at intervals of four strokes only, or two complete revolutions of the crank, and the following phenomena occur during the working of the engine: During the first forward stroke of the piston, a charge of gas and air is drawn into the cylinder; during the first return stroke this charge is compressed. The mixture is then fired by means of the ignition-tube, which gives the piston its impulse on its second outward stroke. During the second return-

stroke the burnt gases are expelled through the exhaust-valve; thus completing a cycle of operations, which is repeated every time a charge is drawn into the cylinder.

The violent and intermittent character of the explosion involves great strength and weight in the working parts of the engine, and very heavy fly-wheels, otherwise the action of the engine would be jerky and irregular; but with fly-wheels of sufficient weight, the running of the engine, even with varying loads, is remarkably steady. The frequency of the impulses is regulated by a governor. So long as the load of the engine requires it, the charges of gas and air are drawn into the cylinder, but should the load decrease, a momentary increase of the speed will result. The governor then comes into action, and prevents the exhaust-valve from closing, so that it is impossible to draw any explosive mixture into the cylinder. The piston therefore ceases to receive any impulses, and the speed of the engine is accordingly checked. In consequence of the heavy strains to which it is subject, involving strength and

weight in its working parts, the gas-engine, in proportion to its power, must be naturally very heavy and massive in its proportions. This is of little consequence where the engine is used for stationary work, but it has prevented the use of internal combustion motors for heavy self-moving engines, such as are required for ploughing and road-traction.

The application of heavy internal combustion engines for road-work is also limited by the difficulty of reversing, but they are very economical in consumption of combustible. The larger gas-engines will run with about 17 cubic feet of gas per brake horse-power per hour, and the smaller sizes with about 25 cubic feet.

There are many very light and powerful internal combustion engines in use for motor-vehicles, both for pleasure cars and merchandise, but whatever advantages they may possess for this class of work, they have not as yet proved themselves of much assistance in agriculture.

The Working of Oil-engines.—Of course gas-engines can be used only where there is a supply of coal or suction gas available. Where this is not the case

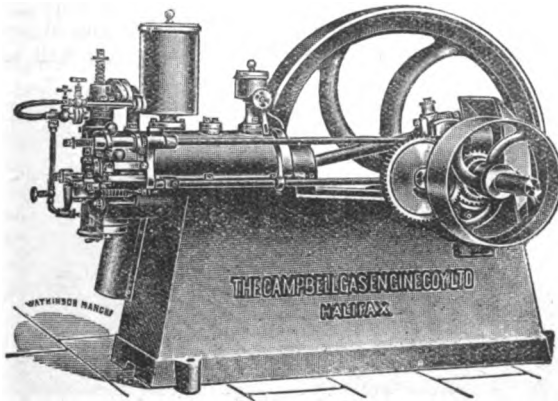


Fig. 334.—Oil-engine.

the oil-engine can be used. This is a modification of the gas-engine, from which it differs very little either in principle or detail. The principal difference is that instead of drawing in a mixture of coal-gas and air, the oil-engine draws in a charge of oil, in the form of spray, together with a certain quantity of air. These pass through a heated chamber, called the vaporiser, on their way to the

cylinder. There the oil spray is gasified, and forms with the air an explosive mixture, which is compressed and fired in exactly the same way as in the gas-engine.

Success of the Oil-engine.—The success of the oil-engine has been phenomenal—more so even than the gas-engine. The moment its potentialities were realised, the demand sprang up, and has

gone on increasing, till now the English makers alone are turning them out in thousands every year. The oil-fuel is cheap and portable, the mechanism is simple and not likely to get out of order. The engine can be started up in a few minutes—a fact which appeals to users of

steam-engines who have to spend an hour or two in raising steam before commencing work. Moreover, the price is moderate, and the cost of foundations and fixing is trifling. Fig. 334 shows a standard oil-engine, such as is manufactured for agricultural work by the Campbell Gas-



Fig. 335.—*The Ivel Motor.*

Engine Company, Limited, of Halifax, England.

AGRICULTURAL MOTORS.

The success of the oil-engine has led to the introduction of agricultural motors,

which are meeting with some support on large farms. What the future of these motors may be on farms is of course uncertain. For working threshing and food-preparing machinery and for road haulage they are well adapted. So far

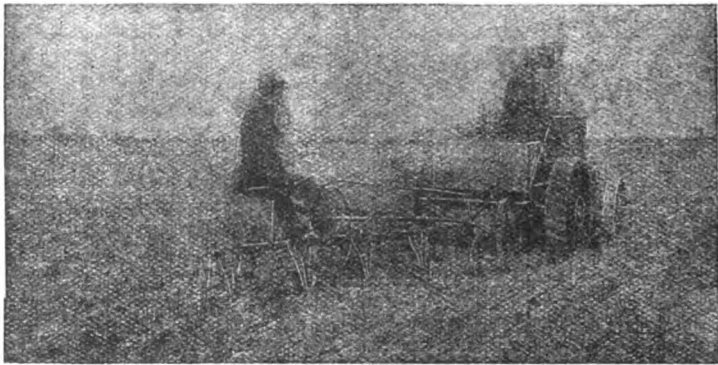


Fig. 336.—*Marshall's agricultural motor.*

their considerable weight has been found to handicap them seriously in field operations, especially on soft lands and in wet seasons. The Ivel motor is represented in fig. 335, and that brought out by Marshall & Sons, Gainsborough, in fig. 336.

SUCTION GAS-PRODUCER PLANT.

An important auxiliary to the gas-engine has been the introduction of the suction gas-producing plant. By this apparatus a gas suitable for use in gas-engines can be produced at a very low

price, the consumption of fuel being as low as from $\frac{3}{4}$ to $1\frac{1}{4}$ lb. of coal per brake horse-power per hour. But as an expensive quality of fuel (Anthracite coal) must be used, it is questionable whether in practice the cost of the power will be less than by the use of an economical steam-engine burning twice the weight of fuel at less than half the cost per ton.

The system, however, is very important, and therefore may be described here. It consists of a gas-producer, built of steel plates riveted together, standing on a cast-iron ashpan, and surmounted by a vapouriser and coal-hopper. The interior of the producer is lined with fire-bricks, and contains a fire-grate at the bottom. The fuel in the gas-producer being in a state of incandescence, as air and steam at atmospheric pressure are drawn through it, the oxygen, hydrogen, and carbon combine in the producer to form a combustible gas, which is suitable for working the gas-engine. After leaving the producer, it is passed through the scrubber, for cooling the gas and cleansing it from impurities. Thence it passes on to the gas-receiver and forward to the engine, where it is used in exactly the same way as the ordinary coal-gas.

Price of Suction Gas-plant.—The price of a 20-brake horse-power engine, with suitable suction gas-plant, delivered and fixed in the United Kingdom, is from £250 to £275. The whole of the plant is simple and easy of management, and can be easily comprehended by any intelligent labourer. Where the work is heavy and continuous, the use of suction gas-plant will be attended with considerable economy. But for small powers and intermittent work it is not likely to supersede the oil-engine.

ELECTRIC DRIVING.

The modern developments of electricity cannot fail to have a special interest for agriculturists. By its means all the work of the farm may be effectually and economically performed. In some parts of the country extensive districts have been appropriated by large electric power distribution companies, whose mains are already laid along many of our country

roads. Farmers whose homesteads are situated near these sources of supply would do well to avail themselves of the facilities offered, by taking their power by motor from the electricity companies, just as many of them take their water-supply from the water-mains.

Economy of Electric Power.—Where the current can be obtained at a cost of about 1d. per unit, it will be found a much cheaper source of power than either steam-, gas-, or oil-engines. The cost of an electric motor is much less than the cheapest engine of equivalent power. It is ready for immediate use, and can be started in a moment by switching on the current. The consumption of current is in exact proportion to the work done, so that no more power is paid for than is utilised. There is no waste, such as is inseparable from keeping a full-powered engine doing light work, like chaff-cutting or cake-grinding.

Every mechanical operation of the farm can be satisfactorily performed by electric motors, and where the machines to be worked are scattered, they can be driven by separate motors, instead of through long lines of shafting, which are found by experience to absorb as much as 75 per cent of the actual power given off by the engine. Thus, dairying machinery at one part of the steading; thrashing, grinding, chaff-cutting, and oat-crushing at another; and a pump for water-supply at any distance from the homestead, could all be worked separately or together by three different motors, costing altogether less than one steam-engine and boiler installed at any one of the three different points of service.

Generating Electric Power.—Only comparatively few farms are so favourably situated as to command a supply of current from public mains, but there are thousands of farm homesteads throughout the country where water power is continually running to waste, which, if utilised, would not only supply power for all the purposes enumerated above, but would light up the farmhouse and out-buildings all the year round for practically nothing. Where such water facilities exist it seems the height of unwisdom not to utilise them. An ex-

penditure of £500 would in many cases provide a water-wheel, or turbine with a dynamo and one or more motors, for driving threshing-machines, as well as the necessary wires for lighting up the house and farm buildings.

Electric Plant easily Worked.—There is an impression that electrical plant is complicated and requires a high scientific knowledge on the part of those who handle it. The fact is just the reverse, for though scientific knowledge is an advantage, yet when once the plant is installed, any farmer with a taste for mechanics, or any intelligent labourer, can be instructed in the practical management of it in a very short time.

WIND-ENGINES.

In recent years there has been a fresh recognition of the value of wind as a motive power. Long before the era of steam, wind power was largely used for grinding corn, pumping water, and other industrial purposes. It has never entirely fallen into disuse, even in this country where fuel is comparatively cheap, and it is not many years since some very large wind-engines were erected in Holland (where fuel is not dear), in preference to steam-engines, for a very large pumping scheme.

The question of water-supply for villages, country-houses, farms, &c., has been forced upon public attention by increasing knowledge of sanitary requirements; and for small schemes of domestic supply, pumps worked by windmills have been found to answer admirably.

Wind as a Power.—Wind is proverbially fickle and uncertain alike in direction, duration, and force. In some countries it is steadier and more reliable in these respects than in others, but in the British Isles it cannot be relied upon at any particular season of the year, or for any particular direction or force. Nevertheless, a certain average amount of wind may be depended upon, and to utilise this a large number of windmills have been erected in this country for purposes of domestic water-supply with the most satisfactory results.

The intermittent character of the

motive force renders it indispensable that sufficient storage tanks or reservoirs should be provided, so that the water pumped during a brisk wind, by night as well as by day, should be conserved for use when the engine may be standing for want of wind to drive it. It is immaterial whether the water is pumped at mid-day or at midnight, in the gloaming or in the small hours of the morning. With a suitable wind-engine and pump erected near the spring or source of supply, the wind may blow where it listeth and the mill will respond. It may blow for a long or a short period, and the windmill will go round when it blows, and stop when it ceases. The experience of most users of wind-pumps is that their cisterns are nearly always full, and seldom or never empty. Owing to the uncertainty of the motive force, however, wind is too unreliable for general power-driving, and its use as a motor is practically limited to water-supply.

Trials of Windmills in England.

The Americans, under the stress of stern necessity, had extensively utilised wind power for small pumping plants long before the revival of its use in this country. Following their example, British agriculturists have benefited enormously by its use. So important was this subject considered that in the early part of 1903 the Royal Agricultural Society of England offered two prizes of £50 and £20 respectively for the best wind-engines suitable for domestic water-supply. There was a large and very interesting competition, and twenty-one wind-engines of English and American manufacture were erected and tried upon the "Royal" show ground at Park Royal, in the immediate neighbourhood of London. The points to which special attention was directed were—

1. Stability of tower, and cost of foundations.
2. Regulation and self-governing.
3. Ease of erection and maintenance.
4. Size of wind-engine relative to power.
5. Price.

The trials took place during the months of March and April 1903. During this

time each mill was subjected to continuous inspection. The force of the wind was carefully observed, and the amount of work done was duly noted. The conditions for all the mills were made as similar as possible. The period over which the trials extended admitted of every variety of weather and extreme variations in the force of the wind. Unfortunately, it happened that the design of the pumps was different in each case. From a scientific point of view this is to be regretted, because a bad mill with a good pump might have given better results than a good mill with a bad pump. It would have been very interesting, and admitted of a better comparison, if each windmill could have been tested working the same pump. This, however, was quite impracticable. Moreover, from the point of view both of the maker and purchaser of windmills, it was only right that the prizes should be given to those makers who produced the best and most effective combination of both pump and wind-engine. The first prize (£50) was awarded to the Goold, Shapley, &

Muir Co., Ltd., Brantford, Ontario, Canada; and the second prize (£20) to Thomas & Son, 64 Broad Street, Worcester, England.

There was a strong similarity in the design of the American wheels, and a good deal of variety in that of the English ones. The trials served to show the general superiority of the British-made mills, for although the first prize was awarded to a Canadian mill, the trials demonstrated that though the design of the American wheels was very good, they failed, on the whole, from weakness of the tower or working parts. It is regrettable that for the sake of a few hundred-weights of extra material the stability of the whole structure should be imperilled.

The trials demonstrated that wind-engines can be produced in Great Britain capable of the greatest service to agriculturists, at a reasonable price, reliable in working, economical in maintenance, and so simple that they can be easily understood and managed by the ordinary staff of the farm.

ROTATION OF CROPS.

Necessity is the mother of invention. "Rotation" in cropping was first introduced because it was found the land would no longer yield a profitable return of the same kind of crop.

Virgin Soils.—Thus in countries newly settled the virgin land is cropped continually with cereals until it will no longer give a profitable return. It is then abandoned, lies in absolute neglect for a number of years, regains in this period of rest some of its lost fertility, and is again made to yield profitable crops, this time under a more liberal and enlightened system of farming. We have here the crudest and most elementary form of "rotation"—a period of continuous cropping followed by a period of enforced idleness.

Object of Rotation.—The rotation of crops is an economical, not an absolute or scientific, necessity. With the knowledge of plant physiology, of the habits

of different forms of plant-growth, and of the manuring of land now at the command of the farmer, it cannot be said to be an absolute impossibility to grow good crops of the same kind on the same land year after year. This indeed is carried out in practice in certain cases—as, for instance, where the land is under permanent pasture and meadow-hay, and on the experimental ground at Rothamsted, where continuous crops of wheat and barley have long been grown with success.

But the practical farmer desires, not to produce a certain result at whatever cost it may entail, but to raise crops which will leave him a profit. The growing of crops in rotation is one of the most effectual and universal agencies employed for this purpose. It affords facilities for clearing the land of weeds, enables the farmer to husband and turn to better account the fertility in the soil, and thus

economises and cheapens the entire production of the farm.

By growing crops in well-arranged rotation, instead of having each crop grown continuously on the same land, the farmer can not only greatly increase the production but also materially lessen the outlay for manures, at the same time maintaining, if not indeed raising, the fertility of the soil.

Thus, therefore, rotation of crops is a fundamental principle in successful agriculture.

"Reasons" for Rotation.—The conditions which render it desirable to grow crops in rotation instead of continuously are,—(1) that while all plants tend to exhaust the soil, they do so in different degrees; (2) that all plants do not abstract the same kind of ingredients or in equal proportions; (3) that the habits of growth differ greatly in plants, some searching for their food down into the subsoil, and others feeding in the surface layers—some occupying the ground for a short time and others for a long; (4) that the "crop residues" of crops differ materially; and (5), that the various kinds of plants differently affect the growth of weeds and the presence of insects.

In accordance with these conditions, the systems of rotations pursued have been arranged, modified, of course, by local circumstances as to climate, soil, and outlet or demand for the produce.

Ingredients Removed by Different Crops.—In the section on "Fertility of Soil," p. 317, much information bearing on the rotation of crops will be found. The table on page 326 states the amounts of the different elements of plant-food removed by the various farm crops. Here we at once see the importance of alternating the crops. The turnip crop, for instance, removes from three to five times as much potash, and from seven to eight times as much lime, as the cereal crops, while these latter absorb ten or twelve times as much silica as turnips. By alternating these crops, therefore, the exhaustion of the soil is deferred, and its natural resources turned to better account.

And there is more to be considered than the actual quantities of plant-food removed from the soil. It is well

known that the fertility of the soil is much affected by the characteristics and habits of growth of the different crops.

Range of Roots.—Some of the farm crops have long roots which penetrate deeply into the subsoil, and others have shorter roots which ramify nearer the surface. The former, such as red clover, lucerne, mangel, and wheat, draw from the subsoil nourishment which would there be beyond the reach of such shallow-rooted plants as barley, turnips, potatoes, and white clover. And thus, by alternating deeply rooted and shallow-rooted crops, the subsoil and surface soil are made to contribute in turn to the produce of the farm, thus giving a greater yield than would be derived from the continuous growth of plants with the same range of roots.

Grass and Soil Nitrogen.—Practical farmers know well that when land lies for three or four years under grass and clover, it becomes enriched with ash constituents and nitrogen, and suitably prepared for cereal crops. The deep searching roots of the grasses and clovers draw from the subsoil ash constituents, which, if consumed by animals, are returned to the surface of the land in the dung. Then in the surface soil nitrogen is collected both from the subsoil and the atmosphere, and is held there chiefly in the form of vegetable matter and humus, from which the succeeding cereal crops will derive appropriate food.

Moreover, grass land not only gathers increased supplies of nitrogen to the surface soil, but also conserves its nitrogen better than does bare land, for it is now well established that the loss of nitrates in drainage is reduced to a minimum when the land is covered by vegetation.

Humus.—By being kept under grass for a time land becomes enriched in humus, an element of great value in soils. It consists of decayed vegetable matter, and "acts effectually as a cement in sandy soils, holding the particles together. Humus is the principal nitrogenous ingredient of soils. A black soil, rich in humus, is sure to be also rich in nitrogen; a soil destitute of humus will contain scarcely any nitrogen. The fertility of virgin soils is largely due to

the nitrogenous humus which they contain."¹

Thus, it is easily understood how land becomes enriched for cereal crops by lying for a time in grass, and why it is easier to maintain fertility with a rotation embracing three or four years' grass than with grass for one or two years.

Leguminous Crops and Soil Nitrogen.—The valuable property possessed by leguminous plants of being able to accumulate nitrogen in the surface soil is dealt with in other parts of this volume, and therefore need only be referred to here as an important consideration in the adjusting of rotations suitable for individual farms. Writing of the power of red clover to enrich soil with nitrogen, Warrington said: "Its roots extend farther perhaps than those of any other farm crop, save lucerne and sainfoin, and being biennial it has a long period of growth. The accumulation of nitrogen at the surface, in the form of roots, stubble, and decayed vegetable matter, is in the case of a good crop of clover so considerable, that the whole of the above-ground growth may be removed as hay, and the land yet remain greatly enriched with nitrogen, and in an excellent condition for producing a crop of wheat." Again: "If crops of winter beans and winter wheat are grown on similar unmanured land, the bean crop will generally contain twice as much nitrogen as wheat. The land is not, however, impoverished for wheat by the growth of beans, for wheat after beans will be a far better crop than wheat after wheat, thus affording a striking example of the advantages of a rotation."²

Period of Growth.—The period of growth and the season of the year during which the crop occupies the ground also have a bearing upon soil fertility and the most economical rotation. It will be seen from the table on page 326, that wheat requires much less nitrogen than turnips, and yet it is well known in practice that the liberal application of nitrogenous manure is much more essential for wheat than for turnips. This arises largely from the difference in

the periods and seasons of the growth of the two crops.

We have seen that nitrification, the production of nitrates in the soil, is most active during summer and autumn, that it becomes greatly diminished or ceases altogether during winter and spring, and that the loss of nitrates by washing away in drain-water is greatest in autumn and winter. Thus the cereal crops grow and occupy the ground just at the time when the soil is comparatively deficient of nitrates. "The autumn and winter rains have frequently washed out the greater part of the nitrates contained in the soil before the growth of the cereal crop commences, and nitrification in the soil has not long recommenced its activity in the summer months when the crop becomes too mature to appropriate fresh supplies of nitrogen. Continuous wheat cropping thus results in a gradual impoverishment of soil nitrogen by winter drainage, over and above the nitrogen actually removed in crops, and thus necessitates a considerable application of nitrogenous manure if fertility is to be maintained.

"A root crop sown early in summer, on the other hand, has at its disposal all the nitrates that would be available for wheat or barley, and in addition, the large supply of nitrates formed in the soil during summer and early autumn. A great part of the nitrates which would be lost by drainage during cereal cultivation is thus assimilated and retained by a root crop, and such crops are found to stand in less need of nitrogenous manure than cereals. By consuming the roots on the land the nitrates collected by the crop are returned to the soil in the form of animal manure, and the land thus prepared to carry a cereal crop. Similar remarks might be made respecting other green crops whose active growth extends into the autumn."³

We thus again see additional reason for the alternation of grain and root crops.

Loss and Conservation of Nitrogen.—It has been seen that the loss of nitrates in drainage water is greatest when the soil is bare of vegetation in the autumn and early winter. Thus by growing only short-lived crops such as

¹ *Chem. of the Farm.*

² *Ibid.*, 60 and 63.

³ *Ibid.*

cereals, the land would be subject to great deterioration in these seasons. On the other hand, by growing crops such as grass and roots, which occupy the land during the entire year, or on through the summer, autumn, and greater part of winter, the nitrogen of the soil is conserved and kept in the surface soil ready for the crops of the succeeding year.

As a special means of conserving soil-nitrogen and preventing waste in drainage, it is a good plan to sow mustard, rape, rye, or turnips broadcast on the stubbles just after the grain crop has been removed. This green crop will grow up rapidly, and will hold in its roots, stems, and leaves much of the nitrogen that might otherwise have been washed away through the drains. The green crop may be fed off by sheep or ploughed in late in winter or early in spring.

Weeds.—The cleaning of the land and keeping it free from weeds are important considerations in arranging the scheme of cropping. Some crops encourage the growth of weeds more than others, and it is only with certain crops that the land can be submitted to a thorough cleaning. With cereals and grasses it is very difficult, indeed almost impossible, to keep down weeds. The root crops, on the other hand, afford excellent opportunities for the thorough cleaning of the land as well as for its perfect tillage.

In this respect the root crop takes the place of the once esteemed but now discounted bare fallow, and apart from its value in itself the root crop fulfils a highly important function in the prevailing systems of rotation. It not only affords admirable facilities for the thorough cleaning and tilling of the soil, but also supplies a convenient opportunity for introducing farmyard dung and other manure to the soil.

"Crop Sickness."—An important consideration in the rotation of crops is the fact that when certain crops are grown continuously or too frequently on the same field the soil is liable to become what is popularly known as "sick" of that particular crop. Thus there is the very stubborn ailment known as "clover sickness," due, it is believed, to some insects, the presence of which is favoured

by the too frequent growing of clover on that particular spot. With turnips there has been similar experience. When grown too frequently on the same land, the risk of loss from "anbury" and "finger-and-toe" would seem to become greater, and to avoid this rotations have been lengthened, by letting the land lie a year or two longer in grass, or by some other variation.

Rotation and Live Stock.—A judicious alternation of crops is as advantageous to stock-rearing as it is to the soil itself. It provides, for one thing, a greater variety of palatable and nourishing food. It also has a freshening or purifying influence on the soil, which conduces to the wellbeing of live stock.

When turnips are grown very frequently on the same land, and consumed thereon by sheep, it would appear that the land is liable to become foul or "stained," so that the sheep folded on it do not thrive properly, becoming subject to stomach and bowel derangement, often even resulting in death, unless an immediate change of food and situation is provided for them. By being put through a course of cropping, and allowed to lie in grass for two or three years, this land, which would seem to have become tired of sheep, is found to be almost as fresh and as suitable for them as ever.

Local Circumstances.—In the foregoing notes we have indicated the chief considerations which regulate rotation in the abstract. In practice it is found advisable to modify the rotation in accordance with soil, climate, and outlet for the produce. Every farmer should proceed upon some well-thought-out plan of cropping, for it is only in this way, assuredly not by any haphazard system, that he will make the most of his land. Yet the intelligent farmer should not be bound, or bind himself, to follow slavishly any particular method of rotation, irrespective of variation in seasons or prices of different commodities. Subject to certain well-understood conditions, essential to ensure that the farm is worked in accordance with the rules of good husbandry, the intelligent farmer should be allowed ample scope to vary the rotation with times and seasons.

Soil and Rotation.—In adapting the

rotation to the character of the soil, the farmer has an excellent opportunity for the exercise of good judgment and experience. It is well known that systems of rotation admirably suited for light or medium soils might speedily ruin a farmer on heavy land. Peaty soil, again, requires different treatment from chalky soil.

Generally speaking, the crops which preponderate on clayey soils are wheat, beans, and grass—with a growing tendency for less tillage and more grazing; for loamy soils, oats, turnips, potatoes, barley, and grass seeds.

Climate and Rotation.—The prevailing climate must, to a large extent, influence the system of cropping. Thus, in the eastern counties of Great Britain, we have corn-growing alternating with root-culture and clover; while in the western districts, with their wet mild climate, we find a preponderance of the pastoral and dairying elements, for which a greater variety and extent of green crops are grown, with just enough corn, oats chiefly, to keep the fields in rotation—two-thirds of the farm perhaps being sown out in permanent pasture.

Rotation and Outlet for Produce.—It goes almost without saying that the prudent farmer will grow the crop which he can sell to best advantage. The situation of the farm with regard to market or outlet for the produce is therefore an important element in deciding as to the course of cropping.

Rotation and Labour.—The question of labour must likewise be considered by the farmer in arranging his course of cropping from time to time. When labour is scarce and dear, it will at once be seen that the best course for the farmer to adopt is to grow crops which require the least amount of labour. To effect this, the extent of root cultivation will most likely be curtailed, and a larger area devoted to grazing purposes.

In such circumstances, a system of mixed rotation might be most suitable—such, for instance, as taking two white crops in succession on the cleanest of the land when broken out of lea which may have lain for three or four years. This would give plenty of fodder for cattle, and the supply of turnips may be

“drawn out” by the economical use of artificial foods.

Grass and Rotation.—The suitability of the soil to carry pasture grasses is another element of importance in the matter of rotation. In some soils the pasture deteriorates so rapidly after the second year as to be practically worthless, while on other soils it maintains a thick luxuriant growth for three, four, or more years. Thus in the former case the land must be sooner returned to the domain of the plough than is necessary with the latter soil.

Arable v. Pasture.—There has been much land laid down to permanent pasture within the last thirty years, in order to lighten the labour bill, and as a remedy for agricultural depression. It answers to a certain extent where the climate is moist, and the soil, both by nature and condition, was suitable for the establishment and maintenance of a good sward; but in a dry climate, and on poor clays, there never was a greater mistake. It fills the ground with rubbish instead of succulent and nourishing grasses; the produce is lessened to a point that will not pay rent and taxes, let alone other expenses; and the costs of cultivation, when breaking up again, are materially increased by the necessity for a thorough cleaning of the land.

Mixed Husbandry needful.—Instead of attempting to form permanent pastures in such cases, it is much better to keep the land in rotation, and merely extend the period under grass,—say, from a five years' course, with two years under grass, to a six or seven years' course, with three or four years under grass. On all but the best soils, or where the land is in tip-top condition, the pasture deteriorates if kept down longer; and this lengthening of the rotation serves all the purpose of economising labour without greatly affecting the produce of the farm. It has been pretty well established that we must adhere to mixed husbandry over the greater part of this country. A return to pasture may be justified in some cases; but, generally speaking, the remedy for dearer labour and lower prices will not be found in that way, but by economy in methods of working, and by a larger production.

Having thus reviewed in detail the

chief considerations which should influence the farmer in deciding as to the course of cropping to be pursued, we may follow up with a few typical rotations pursued in different parts of the country.

Sample Rotations.

Old Three-field Rotation.—Following the elementary system of new countries—a period of continuous cropping followed by a time of enforced rest—came the three-field method of cropping, which is still practised in many parts of Germany. It consists of fallow, followed by wheat, oats, or barley, two-thirds of the land being under cereals, and one-third in fallow.

In the early development of agriculture, when money was scarce and most of the payments were made in kind, this system would allow men whose hands were perhaps better acquainted with the sword than with the plough to settle down and begin the life of a tiller of the soil with little outlay, followed by a large income. Two-thirds of the land would be always under grain, which in those days would amply repay the cost of cultivation.

Infield and Outfield.—In most parts of this country the arable land was at one time roughly divided into "infield" and "outfield" land. The former consisted of the land within easy reach of the farm-steading, and the extent in this division was regulated chiefly by the quantity of dung made on the holding.

This "infield" land was usually cropped thus:—

1. Wheat or barley.
2. Oats or barley.
3. Beans or peas.

All the dung made on the farm was applied to this division, and when the quantity of dung was insufficient, or the land became very dirty, it was bare-fallowed in small sections.

The "outfield" land was cropped on a "starvation" system. It was cropped with oats two or three years in succession, and then left for two or three more years under such grass as might grow up naturally, no grass seeds being then sown. A certain portion of this "outfield" land was always under corn, and the dung resulting from the crops grown on the "outfield" shifts was applied to the "infield" land, so that the latter

was sustained at the expense of the former.

Modern Three-years' Course.—The introduction of turnip culture and the use of artificial manures made it possible for the farmer to adopt new methods of cropping much superior to the primitive systems of earlier times. The earliest rotation of turnips was the three-years' course:—

1. Wheat, barley, or oats.
2. Clover.
3. Potatoes, turnips, cabbages, &c.

Wheat prevailed on the good land, and barley and oats on the poorer soils. It was soon found that this rotation was too short. There was too much of the holding under root crops, and these and the clover were coming upon the same land too frequently. In some cases the clover was omitted, and oats or barley followed the root crop. This was also objectionable—too exhausting for most soils.

Norfolk Four-course.—Next came the famous Norfolk four-course rotation, thus:—

1. Wheat.
2. Turnips and potatoes.
3. Barley or oats.
4. Clover and grass.

In most parts of Scotland the first crop is oats instead of wheat.

This system raises a great quantity of straw and roots, and is with slight modifications practised very largely throughout the country. Indeed it may be taken as the basis of most other rotations.

In this as in the three-years' system it has been found that in most soils the recurrence of clover and turnip crops on the same soil is too frequent, encouraging "clover sickness," "finger-and-toe," and "anbury." To avert these dangers, the four-course system may either be followed with catch-crop variations or extended into a longer course.

Variations of the Four-course.—The most common method of varying the cropping under this system, without departing from its leading principles, is to alternate swedes, mangels, potatoes, cabbages, kohlrabi, &c., on the root-break, so that turnips may be grown on exactly the same spot only once in every eight or twelve years, instead of once in every four

years. Then the recurrence of clover may be similarly delayed by substituting beans, peas, vetches, &c. In some cases wheat and barley are taken in succession, followed by clover for two years, cut the first year and grazed the second, or with (instead of clover) swedes, after an early crop of Italian rye-grass, followed next year by mangels or cabbage. In other cases wheat is followed by winter beans, succeeded by a catch-crop of rape and turnips, the third crop being wheat followed by a catch-crop of vetches and winter oats, swedes completing the course. On other farms, or on part of the same holdings, peas take the place of beans, barley that of wheat in the third year, and mangels that of turnips.

It is, of course, only in southern counties that these catch-crops can be grown to advantage.

Five-years' Course.—The most effective means of averting the evils of the four-course system is to extend the rotation by introducing two or more years' lea. The five-years' course, so extensively pursued in Scotland and other parts of the country, is as follows:—

1. Wheat or oats.
2. Turnips and potatoes.
3. Barley or oats.
4. Clover and grass seeds, cut.
5. Clover and grass seeds, grazed.

This method of cropping has much to recommend it, affording as it does ample scope for farming at high pressure, and yet keeping the bills for labour and manures within reasonable bounds.

Six-years' Course.—A still more economical system is the six-years' course, in which the land is allowed to lie in grass for three years. The labour bill is

lessened, and so is that for manure, while the summer food for live stock is increased, and the farming risks diminished all round. With the decline in the price of grain and the increase in the cost of labour there has been a great increase in the extent of land left under grass for two and three years. Indeed, where the land is well suited for carrying grass, it is now often left under it for four or more years.

In many parts, however, notably in dry districts and on porous soils, the land will not satisfactorily carry grass for more than two years, so that the character of the soil and climate, as well as prices and other influences, have to be considered in arranging the methods of cropping.

Varieties of Six-years' Course.—On stiff soils with an early climate the following six-years' course is sometimes pursued:—

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|------------|----------------|
| 1. Wheat. | 4. Wheat. |
| 2. Beans. | 5. Clover, &c. |
| 3. Fallow. | 6. Roots. |

On medium soils in high condition the system may be varied thus:—

- | | |
|-------------|----------------|
| 1. Wheat. | 4. Clover, &c. |
| 2. Turnips. | 5. Oats. |
| 3. Barley. | 6. Potatoes. |

This, it will be seen, is a heavy course of cropping, requiring liberal and frequent manuring to prevent the exhaustion of the soil. If the turnips are not consumed on the land by sheep, it may be advisable to top-dress the crops of barley and oats.

The five and six years' rotation is pursued with numerous other variations. The following are examples of the latter:—

Year.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.
1st.	Potatoes.	Oats.	Oats.	Oats.	Oats.	Wheat.	Wheat.
2d.	Wheat.	Wheat.	Beans or potatoes.	Roots.	Turnips.	Roots.	Barley.
3d.	Turnips.	Roots.	Wheat.	Wheat.	Wheat.	Wheat.	Roots.
4th.	Barley or oats.	Barley.	Roots.	Barley.	Beans.	Beans.	Oats.
5th.	Clover and grass.	Clover and grass.	Wheat or barley.	Clover and grass.	Wheat.	Barley.	Clover and grass.
6th.	Pasture.	Pasture.	Clover and grass.	Pasture.	Clover and grass.	Clover and grass.	Pasture.

The first of the above is pursued on many farms in the south of Scotland and elsewhere. Nos. 2, 4, and 7 are met

with in the midland counties of England and elsewhere; No. 3 is the prevailing East Lothian six-course; No. 4 is found

in the west of Scotland and other parts; and No. 6 on strong soils in Bedford and other English counties.

Seven-years' Course.—There are also many varieties of seven-years' rotations. In Scotland there are usually three or four years' grass in this course. In potato-growing districts of Scotland the following course, or one similar, is often pursued:—

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|-----------------------|----------------------|
| 1. Oats or potatoes. | 4. Turnips. |
| 2. Potatoes or beans. | 5. Barley or oats. |
| 3. Wheat. | 6. Clover and grass. |
| 7. Pasture. | |

Others take in succession oats, potatoes, turnips, and barley, followed by clover and grass for three years.

A seven-years' course pursued with success on some good farms in the north of Scotland is as follows:—

- | | |
|----------------------|----------------------|
| 1. Oats. | 4. Oats. |
| 2. Barley. | 5. Clover and grass. |
| 3. Turnips. | 6. do. do. |
| 7. Clover and grass. | |

For the barley crop after oats a light dressing of dung is spread in the autumn and covered with a break-furrow. In spring the land is harrowed and ploughed with a shallow furrow.

A course of cropping pursued on the wolds of Yorkshire is as follows:—

- | | |
|----------------------|-----------|
| 1. Wheat. | 4. Peas. |
| 2. Roots. | 5. Roots. |
| 3. Barley. | 6. Oats. |
| 7. Clover and grass. | |

Others think it better to let oats follow the clover and grass, and take wheat in the sixth year, after roots.

Many more samples might be given, for in the courses of cropping pursued throughout the United Kingdom there is almost endless variety. Enough has been said to enforce the importance of every farmer considering carefully his own peculiar circumstances as to soil, climate, market, supply of labour, &c., and thus be able to pursue such a course of cropping as will give him the best results.

General Rules.

In deciding as to the course of cropping to be pursued, the following general rules should be kept in view: (1) crops which have deep penetrating roots should be followed by those having

shallow wide-spreading roots; (2) crops of the same order should not too frequently succeed each other; (3) crops which encourage the growth of weeds and prevent the cleaning of the land should be separated by as wide intervals as the circumstances of the farm will permit; (4) crops which are grown for seeds should be succeeded by those grown for their roots or foliage, and which are largely consumed on the land on which they are grown.

Food-supply.—An important object to bear in mind is to so order the succession of crops as to provide an even and continuous supply of food for the stock, so that the farmer may not be under the necessity of one year buying a large number of stock, and next year greatly reducing the number.

Distributing Labour.—Another point of great importance is the distribution of labour over the year—growing crops which require labour at different times, and avoiding an excess of those which press for labour at one particular season, leaving the rest of the year with comparatively little to employ the farm hands.

Varieties of Crops.—When a farmer has decided on a rotation, and to have, say, one-third or one-fifth, or whatever proportion of his land, under roots and green crop, he has still to consider not only how many varieties of these crops are to be grown on this section of the farm, but the most suitable proportion in which to grow the different varieties. The finer the climate and soil of any given district, the more important is this consideration; but, even in less favourable circumstances, it is not simply a question of turnips for the cattle or sheep of the farm. The days when the green crop could be limited to turnips, with a small patch of potato plant, are past and gone. Swede turnips, yellow and white, it is true, follow each other in such sequence, both in the time of sowing and the time of lifting and feeding, as to enable the labour of men and horses to be more evenly distributed over the seasons than would be the case if the whole of the turnip crop consisted of only one of these varieties. But this object is more fully secured by bringing in other crops also. If soil and climate

are suitable to their growth, it is impossible to have too great a variety. In addition to white, yellow, and swede turnips, the majority of farms can grow mangold or beet, carrots, and parsnips; and as carrots and parsnips can be put in during March, mangold in April, swedes in May, and late turnips in June, this extension offers many advantages. Besides these there are many other green crops suitable, any one of which, perhaps, can be fed in the field with less loss than turnips during the winter. There are many varieties of field cabbage; also rape, and khol-rabi.

With corn crops the question is even

more important. Harvest time is short, and the simultaneous ripening of all our crops of grain in one single month, or less, causes a very imperfect distribution of the labours of the year; and if that one month happens to be a wet one, the whole of our corn crops are damaged to an incalculable extent. If we could have a variety of grain crops coming to maturity at different times during the summer months, it would be an immense advantage in many ways, but our summers are too short to admit of much variation in the periods of the ripening of our cereal crops, which require most of the time for actual growth.

BARE FALLOW.

The time-honoured custom of bare-fallowing has almost come to an end. Three agencies, distinct, yet associated, have combined to bring this about. The fall in the price of wheat, land drainage, and the application of science to the practice of agriculture, have so discredited bare fallow as to render it a thing of the past, except in the very stiffest of soils.

One crop of wheat, with the price at little more than 30s. per quarter, will not bear the rent and labour of two years. Where it could be avoided, therefore, bare fallow would of necessity have been discontinued. But by the advancement of agricultural education and the introduction of artificial manures, the farmer is enabled, in all except the very stiffest soils, to emulate, and indeed to surpass, the beneficial influence of bare fallow without leaving the land uncropped for a single season. Thus it has happened that the practice of bare-fallowing, once very common in the British Isles, has fallen into disrepute, and is now pursued only in exceptional instances, almost entirely on strong clays, which are so stiff and unpliable as to be unsuited for any of the standard root or fallow crops.

Fallowing and Loss of Nitrates.—Another influence which has operated against the practice of bare-fallowing is the discovery of the great loss which is

liable to occur in uncropped land by the washing away of nitrates in drainage water. This occurrence is fully noticed in other parts of this work, notably in the section dealing with Rothamsted Experiments, and should be duly considered by every farmer who contemplates fallowing.

Objects of Bare Fallow.—The objects of bare fallow are to replenish exhausted soil by the natural agencies of rest and disintegration, and to afford an opportunity of eradicating weeds. By the growth of crops which are removed from it, the soil is robbed of its supply of available plant-food. To restore this lost fertility, our forefathers resorted to the device of allowing the land to "rest" for a year, and of tilling it so thoroughly during this time of leisure as not only to eradicate weeds, but also to so disintegrate the soil as to replenish the upper layers with available plant-food.

Beneficial Effects.—This may be exerted in three ways. First, by cleaning the land of weeds,—the repeated tillages getting rid of couch-grass and other perennials, while, at the same time, annual weeds are germinated and destroyed by the next cultivation. Secondly, by improving the texture or physical condition of the soil, and increasing tilth. Thirdly, by increasing soil fertility. This, of course, is the principal result of increas-

ing the amount of tilth, and apart from that it cannot be said that land gains in fertility by a summer fallow. On the contrary, it has been proved at Rothamsted, and elsewhere, that in the course of a given number of years more wheat can be grown by continuous cropping than by fallowing every second year when no manure is used in either case.

Production of Nitric Acid.—"The production of nitric acid," says Mr R. Warington, "is probably the most important result of a bare fallow. In ordinary soils at Rothamsted, left as bare fallow, there has been found at the end of the summer 34.55 lb. of nitrogen per acre in the form of nitric acid in the first 20 inches from the surface, the quantity depending on the richness of the soil in nitrogenous matter and the character of the season. The whole amount of nitrates produced during the fifteen months that the land remains without a crop has been estimated at not less than 80 lb. of nitrogen per acre for the arable fields under ordinary cultivation at Rothamsted. Supposing the season of fallow and the following winter are fairly dry, this increase in the available nitrogenous food will probably enable the soil to produce twice as much wheat as it could do without a fallow. If, however, the soil is exposed to heavy rain, the nitrates produced will be more or less washed out, and the benefit of the fallow greatly diminished. Bare fallow can be used systematically with advantage only on

clay soils and in a tolerably dry climate; under other circumstances a continuance of the practice must result in a serious loss of soil nitrogen."¹

Objections to Bare Fallows.—Perhaps the smallest objection to bare-fallowing is that it entails expense without immediate profit. A year's rent and taxes, besides the heavy expense of working the fallow, have to be paid entirely out of capital, as there is no crop at all to balance the outlay. If a summer fallow were the means of doubling the next year's crop, something might be said in favour of it; but, as we have seen, more wheat can be grown by continuous cropping than by bare-fallowing every second year. Add to this that much of the good effect of bare-fallowing may be produced by an application of lime, and it becomes not only quite unnecessary as a means of maintaining soil fertility, but an impossible practice under the double influence of dear labour and cheap corn.

Clover Crop v. Bare Fallow.—One of the Rothamsted experiments illustrates how much may be gained by a clover crop in place of a bare fallow. One of the fields is farmed under a four-course rotation—swedes, barley, clover or fallow, wheat; one-half of the plots growing clover, and the other fallowed before the wheat. The better the clover the better the ensuing wheat, and a comparison of the succeeding crops even is altogether against the fallow plot:—

	Clover Hay.	Wheat.	Swedes.	Barley.
	cwt.	bushels.	tons.	bushels.
Clover plot . . .	76.7	39.5	19.4	36.3
Fallow plot . . .	—	32.5	19.0	28.3

Thus, although nearly four tons of clover hay were removed, the residues, roots, and stubble were sufficient to increase the wheat crop by 21 per cent; the root crop, which came next, by 2 per cent, although the same manure was put on both crops; and finally the barley, three years after, by 28 per cent.

"Summer" and "Winter" Fallows.—In the popular mind "bare fallows" mean only summer fallows, but in the

literal sense all the autumn-ploughed land which is left bare in winter is fallow land, whether it is called so or not. This gives a wider significance and importance to the subject of bare fallow. There can be little doubt that the farming of the immediate future will demand a practice that does away with the need of winter fallows as much as of summer fallows;

¹ *Chemistry of the Farm*, 58.

for if there is a loss of fertility by leaving land bare in summer, how much greater must that loss be in winter, when the soil, unless frost-bound or covered with snow, is being continually washed by heavy rains? It would be better to leave the stubbles unploughed until spring than to plough them up in autumn, and leave them bare all winter, for in the latter case fertility is only wasting; but there would seldom be any tilth for the spring crops if the stubbles were left unbroken, and the only alternative is winter cropping. This is still more necessary where land is left altogether bare after potatoes or turnips.

If the land is in good condition, a winter crop, such as vetches, rye, rape (the winter, not the summer, varieties), kale, and cabbage, will grow in good arable districts in these islands; and if put in early enough will afford a moderate amount of remunerative spring food for stock, in time to let the land be cleared for the turnip or other crops to follow.

Methods of Fallowing.—The principle of bare-fallowing has been employed in numerous ways to effect the desired objects of replenishing and cleaning the soil. In early times it is believed that more than one year's rest was given at a time. In the more distinctly historical ages one year has been the usual duration of the bare fallow. As to the interval between the bare-fallowings, practice has varied, and still varies greatly. Morier, in his Cobden Club Treatise (1870) on the "Systems of Land Tenure," refers to a three-field system of cropping, with "each field lying fallow once in three years," as having been practised in the first century.

This three-field system was at one time largely pursued in this country, and it was "last heard of" in the county of Durham. Under this system two-thirds of the land would always be producing grain or beans, the other third being bare fallow.

In the better classes of wheat soils, rich in inherent fertility, the fallow came at longer intervals, in every fourth, fifth, or sixth year, according to the character and condition of the land. The crops grown between the fallows would be wheat, beans, oats, and clover, alternated so as to give as many crops of wheat as

possible in the rotation, yet without cropping with wheat in two successive years, or allowing wheat and oats to follow each other.

Where fallow exists, it takes the place of the root crop in the rotation.

Land to be Fallowed.—The portion of land to be fallowed will be the strongest clay on the farm, some piece of land which cannot be otherwise turned to good account. It may be so infested with weeds as to render it impossible to thoroughly clean it in time for an ordinary crop. Other conditions being equal, the portion of the shift to be fallowed will usually be that farthest from the steading, so that the green crops may be as near thereto as possible.

Treatment of Fallows.—The treatment of bare fallows will perhaps extend over the greater part of eight or ten months. It begins in winter, finishes in the following August or September, and consists of several ploughings and grubbing, or draggings, with thorough harrowing, rolling, clod-crushing, and weed-gathering. It is impossible to determine beforehand how many times bare fallow should be ploughed, harrowed, grubbed, and clod-crushed, to make it clean; but it should be borne in mind that one of the main objects of bare-fallowing is to make the land thoroughly clean.

In many cases the bare fallow is ploughed or grubbed four or five times, at intervals of four to seven weeks; and the number of turns of the harrow must be left to the judgment of the farmer at the time.

Overworking Fallow.—It was at one time believed that the perfection of bare-fallowing was to work on till the land was reduced to a very fine tilth. Experience has proved it better for wheat to have a good-sized clod upon the surface in winter, however much the ground below may be pulverised. It is a decided mistake to reduce the surface of the fallow to a fine smooth condition in the autumn; and rolling in the autumn, after or just before the sowing, should never be practised.

Prevailing Methods.—Common methods of working fallow land are as follows: The fallow land is the last stubble to be ploughed in winter. The plough-

ing is done in the same manner as for potatoes and turnips. Then comes cross-ploughing in spring. If one furrow has been given after cross-ploughing, it will be as much as time will afford from working the potato and turnip lands; and as the bare fallow is not likely to be worked for some time, it is better to keep it in the rough state from the plough, because, should dry weather ensue, it will moulder down; and should wet weather set in, the rough land will be less tough to work.

When leisure at length permits attention to the bare fallow, its state should be particularly examined.

Weeds.—Should the weeds consist of fibrous and fusiform-rooted plants, they will be easily shaken out by the harrows in dry weather; but should their roots thread themselves through the hard clods, they cannot be detached by the harrows. Inattention to the state of the weeds at this stage may cause double work at a subsequent time. Clods containing portions of tenacious roots, knocked about in dry weather, will be broken into smaller pieces; but so will the roots in them, and the land be as far as ever from being cleaned. The best plan, then, is to allow the roots to grow, that the force of vegetation may break the clods, or render them easily so by a clod-crusher after a shower of rain has moistened them.

A precaution in the use of a roller should here be given. If the soil is in a mouldy state, rolling will only bury the hard clods with the roots in them, not break them. The harrows in 2 or 3 times will break them better than rolling.

After a good clod-crushing, the land should be harrowed a double time, first one way and then across.

Collecting Weeds.—The weeds will then be collected on the surface. It is not expedient to gather them immediately, as a good deal of fresh soil adheres to them. With an interval of one or two dry days, the soil will be easily shaken off.

The chain-harrow may be used to assist in collecting the weeds, and the work will be completed by graips or forks, or by the bare hand.

Disposing of Weeds.—In some cases the weeds are collected in heaps and carted off to be burned, destroyed, or converted into compost. In others they are

wholly or partially burned on the land. It is not easy to so thoroughly burn weeds on the land as to prevent future growth; but this danger will be avoided if any roots found in the bottoms of the heaps are carefully removed when the ashes are being spread. Many farmers, however, prefer to make compost of the weeds, thus agreeing with Lord Kames, who exclaimed, "What better policy than to convert a foe into a friend?"

Kentish Practice.—In Kent, as in other parts of the country, only the stiffest soils are left in bare fallow, and even on these it is not now extensively practised. Mr Solomon, Dartford, Kent, writing in 1888, says: "A bare fallow is often taken after oats, or it may be after seeds. They plough even before Michaelmas if possible, then leave the ground till early in the year, and then plough again—it may be across or by turning back the furrow. The ground receives about four more ploughings and about a dozen or so harrowings and draggings, exposing couch and other weeds to the hot suns of July and August (which is all the weeding deemed necessary). Where we had some of our marshes here under plough the following was the rotation: Fallow, wheat, beans, wheat, and clover, but this was only a 'bastard fallow,' because they took one cut of clover and then ploughed up in June or beginning of July. The land was immediately cross-ploughed, so as to lay it up roughly, and it was left till September, when it was ploughed again for wheat, which was sown early in October."

Dung for Bare Fallow.—The manure for the bare fallow consists mostly of the part of the farm-dung which was left in the courts when the dung was taken away for the turnips, and that since made by the cattle and horses. Compost is now largely used for bare fallow. Every material convertible into manure should be used, and ash-courts, privies, cesspools, pigeon-house, poultry-houses, ponds, and ditches, cleared out at this time. These materials are compounded together with the farm-dung, straw, and compost, into a large dunghill in the compost-yard, ready for the bare fallow by the end of July. The dung is not much heated for bare fallow, as it has time partially to decompose in the soil before the wheat

is sown; but should there be no time for that, it should be putrefied the more, that the wheat may not suffer in winter in ground hollowed by unrooted dung.

Preparing for Dung.—An ordinary preparation in bare fallow for the dung is to feer it into ridges. If the land has been drained, which it ought to have been at some time, the feering should be for casting the ridges together; and as the land will be seed-furrowed when the wheat is sown, this feering for casting should leave one single ridge on the side of the field at which the ploughing commences—so that in seed-furrowing the ridges may be cast together in pairs from side to side of the field. If the land has not been drained, it should be gathered up from the flat, leaving a half ridge on the side of the field, that the ridges might be completed in gathering up the seed-furrow.

Spreading Dung.—The dung is carted out to the feered field, hawked out of the cart by each ploughman in heaps upon each successive ridge, in such quantity per acre as may be determined on. The dung should be discriminatingly laid down, according to the wants of the soil in different parts of the field, the poorer soil on the heights of knolls having more and the deeper hollows less. Bare fallow is seldom so heavily manured as for green crops. Common dressings consist of from 8 to 12 tons per acre.

Field-workers should spread the dung evenly over the surface with common graips or forks, and the ploughs cover it in rapidly from the heat of the sun. If the heat is scorching, as many field-workers should be employed as to keep the plough going. It is too common a practice to spread the dung for bare fallow some time before it is ploughed in.

Drilling Fallow.—Some prefer ploughing in dung for bare fallow in drills. The drills are made in the single way, diagonally across the future ridges. The dung may be thrown in graipfuls from the cart as described for turnips or potatoes; but formerly the more general method was to drag the dung from the cart into heaps in the drills. The heaps are divided by a field-worker across three drills, and three workers spread the dung along the three drills with small graips, and the ploughs cover it in returning

from making the drills, as is done in dunging for potatoes and turnips. The dung is thus quickly spread and covered in, and the land remains in drill until it is seed-furrowed for wheat. In this mode of manuring bare fallow, the dung, being in bulk in the drill, it putrefies readily; and after the drills are harrowed down, and the land seed-furrowed, the dung becomes intimately incorporated with the soil.

Folding on Fallows.—Bare fallow is manured in England by sheep folded within hurdles or nets, and fed on tares or other forage, and perhaps cake or grain, brought to them. As one break of land is sufficiently manured, a new one is enclosed. This practice is called folding, and is pursued with success.

"Bastard" Fallow.—In some cases rapid-growing crops—such as white mustard (*Sinapis alba*) or rye—are sown on the fallows early in summer, and folded by sheep when they are a few inches above ground. This is one form of "bastard" fallow,—other forms of "bastard" fallow occurring where a catch-crop of clover, vetches, or some other suitable plant is taken early in the season, and the land ploughed up early in summer, and then worked as fallow.

Green Manuring.—Another mode of manuring bare fallow is sowing some kind of rapidly growing plant upon it, and then ploughing it in. White mustard (*Sinapis alba*) is employed in this manner with advantage. About 12 lb. of the seed is sown on an acre, and after the plant has grown about four inches it is ploughed in. This operation is known as *green manuring*, and may be practised with many other plants. Rye is so employed.

In some cases two or three successive growths of mustard are thus ploughed into fallow land. As soon as the first crop is nearly at its full growth it is rolled flat, the land is ploughed, another seeding of mustard sown, the crop again ploughed in, and perhaps a third crop treated likewise. The first crop of mustard is sown in spring, after the fallow has received its second ploughing.

By this plan a great amount of vegetable matter is incorporated with the soil. By the decay of this matter the clays must not only be loosened in tex-

ture, but also enriched in the nitrogenous ingredients so essential for wheat. It is a cheap and effective system both of manuring and cleaning stiff land, unsuited for growing roots.

Objection to Green Manuring.—There is undoubtedly much to be said in favour of this system of green manur-

ing for stiff soils. Yet it is perhaps better farming to combine the growing of these catch-crops with the folding of sheep. "Having succeeded in obtaining a crop, it is clearly better," says Professor Wrightson, "to feed it off with sheep than to partly waste it by ploughing it in."

MANURES AND MANURING.

In the advanced agriculture of the present day the question of manuring possesses far more importance and involves greater difficulties than were associated with it in the elementary farming of olden times. The extension and accumulation of knowledge, in regard to the maintenance, utilisation, and recuperation of fertility; the discovery and development of new sources of manurial commodities; and the vastly increased and still growing home consumption of farm produce of all descriptions, have with their combined influence contributed largely to the great revolution which, since 1840, has taken place in British farm practice.

The farmer can no longer wait for the recuperating power of nature to restore reduced fertility. He is not content to merely "turn over," as it were, the natural store of plant-food which the soil possesses. Before the advent of "artificial" manures and feeding-stuffs the prevailing system of farming was little else than a "turning over" of the inherent fertility of the soil—the abstraction of fertility from one field in certain crops, and the returning of it, or a great part of it, to another field in the shape of farmyard manure. This, however, was a slow process, quite unequal to the wants, the aspirations, and resources of the progressive age in which we live.

A speedier, more intense, more artificial system of farming has arisen, and to make provision for the greater demands which are now made upon the productive powers of the soil, active and persistent attention has for years been devoted by scientists, capitalists, and practical farmers to the all-important question of *manuring*. Indeed the de-

velopment of the manure-trade is to some extent the cause rather than the result of the increased activity and progress of agriculture. They have grown up, as it were, hand in hand, the one fostering and encouraging the other.

By the discovery of vast natural deposits of manurial elements, and by the manufacture of useful fertilisers from waste products and other material, great possibilities, hitherto undreamt of, have been placed in the hands of the farmer. By means of these agencies it is possible for him to vastly increase and hasten the production of his farm—not only by adding to the supply of plant-food already in the soil, but also by so stimulating, equalising, and preparing that supply, as to render it far more serviceable and nutritious to the growing crops.

The farmer is not now dependent upon the residue of his crops for the restoration of fertility to the soil. So far as concerns the question of the fertility of the soil, the farmer may now grow what he pleases and sell what he pleases. The abstracted fertility may be replaced by purchased fertilisers, so prepared and proportioned as to return to the soil in the most useful form the exact quantities of the elements of plant-food withdrawn by the crop.

It is not to be said here that this system of selling crops and buying artificial manures is preferable to the older and still more general method of consuming a large portion of the crops on the farm, and so restoring fertility by farmyard dung or by droppings on the fields being grazed. The point is mentioned merely for the purpose of indicat-

ing the vastly extended scope which the development of the manure-trade has imparted to the practice of farming.

In connection with the maintenance of soil fertility there has arisen a new element of absorbing interest in the discoveries relating to soil bacteria, and in particular to the appropriation of air nitrogen by leguminous plants. As the result of these discoveries new lines of research are being opened up which give promise of much usefulness to agriculturists.

It is thus seen that the subject of *manures and manuring* is now one of surpassing importance. It has, indeed, become the very keystone of British agriculture. Therefore it is deemed imperative that in *The Book of the Farm* the subject should receive somewhat exceptional attention. It is dealt with more fully than has before been attempted; and while dogmatism as to the precise composition and quantities of specific manurial doses has been avoided, an effort is made to submit in convenient form such information as will safely guide the intelligent farmer in the economical and efficient manuring of his land.

Diversity of Views and Practice as to Manuring.—There is probably no process connected with agriculture as to which there is more difference of opinion, or in which greater diversity of practice prevails, than the manuring of land. This remark, too, is quite as applicable to professional chemists as to practical farmers. To attempt to reconcile all these contradictory views and customs would be hopeless; yet in the majority of cases the contradiction is more apparent than real. The more intimately one becomes acquainted with the routine of farm management in the various parts of the British Isles, the less is one inclined to dogmatise and to assert that a certain system is right and all others wrong. The system which gives the best results in the cold regions and light friable well-drained lands in the north of Scotland, may be utterly unsuited to the stiff clayey lands of England, or the moist soil and mild climate of the Emerald Isle. One may be assured that the marked divergencies in farm practice are not mere accidents. As a rule, they

will be found to be fully justified by variations in local conditions, differences in soil, climate, and objects and possibilities of the farmer. Then, as to the differences amongst men of science, it should be borne in mind that the great field of agricultural chemistry is only in process of exploration, and that while our knowledge regarding its wonderful truths has, in recent years, grown with gratifying rapidity, it is still far from being perfect and entire.

In dealing with the subject of manures and manuring, the Editor has been deeply impressed with these considerations, and, keeping them in view, he has sought the counsel of many recognised authorities. The writings of our most eminent chemists and practical agriculturists have been carefully consulted and freely drawn upon, notably those of Johnstone, Cameron, Voelcker, Anderson, Lawes, Gilbert, Wilson, Sibson, Morton, Ville, Liebig, Hellriegel, Wrightson, Warington, Aitken, Jamieson, Falconer-King, Aikman, Macadam, Bernard Dyer, Lloyd, Wright, Hall, Cooke, Fream, Curtis, Brown, and many other recent investigators at home and abroad. And from several experienced practical farmers, who have made a special study of the subject, and who reside in and farm different parts of the kingdom, the Editor has received most valuable help and advice in his effort to present the readers of this work with useful information as to the economical manuring of land.

EXHAUSTION AND RESTORATION OF FERTILITY.

In the section on "Fertility of Soil" (p. 317 in this volume), the principles relating to the existence, exhaustion, and restoration of fertility in soils are fully explained. The reader should be familiar with what is said there before perusing what follows here.

Abstraction of Fertility.—It has been seen that the fertility of the soil becomes reduced by the removal of ingredients in crops and animals raised upon it, and by soluble matters being carried away in drainage-water. It is also more than probable, as will be explained in connection with the Rotham-

sted experiments in this chapter, that loss of plant-food occurs through evaporation of free combined nitrogen.

Prior to the introduction of artificial manures, farmers relied almost entirely upon farmyard dung to replace the abstracted fertility. This, however, was not sufficient, for much of the ingredients of the soil were sold off in the form of grain, meat, milk, cheese, and other produce. It is thus obvious that, if no other means of restoring fertility had been found, the soil would have, in course of time, become exhausted.

Deferring Exhaustion.—The agents which were most effective in deferring this exhaustion were careful and seasonable tillage, drainage, subsoiling, the decay of the roots of crops, and the rotation of crops, particularly the inclusion of leguminous crops in the rotation. The combined influence of these agents is certainly by no means insignificant. It has been well shown in the Rothamsted experiments that tillage and the decay of the roots of crops have a very important bearing upon the duration of fertility in soil.

It is a curious and important fact that the growth of crops in itself, while robbing the soil of certain ingredients, tends to enrich it in other elements of fertility. Certain plants absorb nitrogen from the atmosphere, and draw nutritious ingredients from the subsoil. By the decay of their roots they thus leave the surface soil richer in certain elements than it was before. And the larger the crop the more does it enrich the soil in these elements, for the greater is the residue of plant-food in the roots which remain in the soil.

Restoring Fertility.—But it is clear

that something more is necessary to restore to the soil the particular elements removed in the produce exported from it. For this restoration we have now at hand an exhaustless store of artificial manures.

Ingredients Removed by Crops.

—The important question now arises: What are the ingredients which are removed in crops, and what are the quantities of each? As to the elements of plant-food and their sources, see p. 319 in this volume.

On p. 326 of this volume will be found an exhaustive table, showing the weight and average composition of ordinary farm crops in pounds per acre. From that table it is easy to calculate the quantity of each ingredient of plant-food removed in any rotation of the ordinary farm crops. And from the full explanations which accompany the table, useful deductions may be drawn as to the manurial treatment which should be pursued under the various systems of cropping, stocking, and disposal of crops and stock.

The subject is so fully and clearly dealt with by Warington, in the pages referred to, that any further discussion here of the general principles relating to the exhaustion and restoration of fertility would be needless repetition.

Exhaustion in a Norfolk Rotation.

—It may be interesting to show here in tabular form the quantities of the chief elements of plant-food which would be withdrawn from the soil in the course of the Norfolk rotation of wheat, turnips, barley, and clover; and with this total is contrasted the amount of these ingredients which would be returned in an ordinary dressing of farmyard manure—8 tons or 16 yards of dung:—

Crop.	Dry Matter.	Nitrogen.	Potash.	Magnesia.	Phosphoric Acid.
	lb. per acre.	lb. per acre.	lb. per acre.	lb. per acre.	lb. per acre.
Wheat, 30 bushels per acre. . . .	4183	48	28.8	7.1	21.1
Turnips, 17 tons "	4657	112	148.8	9.5	33.1
Barley, 40 bushels "	3827	48	35.7	6.9	20.7
Clover, 2 tons "	3763	102	83.4	28.2	24.9
Totals		310	296.7	51.7	99.8
Rotten farmyard dung, 8 tons per acre		96.8	95.2	18.94	48.0
		213.2	201.5	32.76	51.8

It is thus seen at a glance that an ordinary dressing of farmyard manure, say 8 tons or 16 yards per acre, applied once in the above four-course rotation, would restore barely one-third of the elements of fertility removed by the crops. Such a large dressing as 24 or 25 tons of dung per acre is impracticable; hence the economy and advantage of having at command the various artificial fertilisers in which, in a highly concentrated and readily available form, the deficient elements may be supplied.

Removal and Return of Plant-food in Different Systems.—This supplemental work is indeed the chief function of artificial manures. Upon all farms, less or more farmyard dung is made; and as a means of restoring fertility, it is first reckoned upon and employed. Under certain systems of farming, where not only the great bulk of the produce of the farm, but also large quantities of purchased foods, are consumed on the farm by stock, the quantity of dung may be almost sufficient for all the manurial requirements of the holding. Indeed, under such a system, the manurial residue of the purchased foods might supply more plant-food than would be exported from the farm; and thus, without the aid of any of the artificial fertilisers, there would be an accumulation rather than an exhaustion of fertility. But extreme cases of this kind are very rare.

The extreme on the other hand is where the growing and selling of crops are the main features in the system of management, and where few or no stock are kept beyond what is necessary for the working of the farm.

Between these two extremes there are many gradations—an endless variety of systems, in which there is an ever-changing relation between three great factors in successful agriculture—viz. (1), the amount of plant-food withdrawn from the soil; (2) the amount returned in farmyard manure; and (3) the quantity of purchased fertilisers necessary to make up the deficiency in the latter, as compared with the first, or to furnish any increased fertility which the farmer may desire to impart to the land.

Sum and Substance of Successful Manuring.—Here, then—in securing the proper relations of these factors—we

have the sum and substance of successful manuring. It is by no means a simple matter. It is beset with many problems requiring the most careful and intelligent study, as well as technical knowledge. The farmer has to consider not only what quantities of the various elements of plant-food he would have to purchase to make up the deficiency in his supply of farmyard manure. He must also see that he procures these elements from the best and cheapest sources at the time, and that they are in the forms most suitable to his objects.

And it has to be kept in view that the ascertaining of the amount of purchased manure necessary to supplement the farmyard dung is not the simple matter the uninitiated might at first sight regard it. It is not sufficient to merely subtract the supply of plant-food in the stock of dung from that contained in the crops removed from the soil. For instance, we have seen from the table on page 448 that during the four-course rotation there mentioned the quantities of plant-food removed in the crops would exceed those returned in 8 tons of dung by 213 lb. of nitrogen, 201.5 lb. of potash, 32.76 lb. of magnesia, and 51.8 lb. of phosphoric acid, per acre.

Resources of the Soil to be Reckoned.—Now it is not enough for the farmer to have ascertained this. If he were to supply the full quantity of each ingredient here represented as deficient, he would most likely be pursuing a wasteful system of manuring. The natural resources of the soil must be reckoned with. In many soils there is a great natural store of certain elements of plant-food, which will be capable of furnishing the wants of crops for several years to come. For instance, if it is a clayey soil, there will most likely be such an abundance of potash in it as that any direct application of this element would, for the time being, be entire waste of money, perhaps even hurtful to the crop.

The farmer has therefore a fourth factor to reckon with—namely, the *reserve* of plant-food in the soil.

Chemical Analysis Unreliable.—The accurate ascertaining of the quantity and condition of this “reserve” of plant-food in the soil is perhaps, of all, the most “knotty” point in the whole

question of manuring. The acumen of the chemist long failed in this particular point. By the aid of his powerful acids, alkalies, and other decomposing agents, he can tell us the entire quantity of any element in the soil and subsoil, and until recent years he could not go further. Now, however, promising attempts have been made in the introduction of analytical processes aimed at, determining definitely how much of that element exists in a form available to the plant, and how much of it is locked up in combinations which the weaker acids at the command of the plant are unable to break up. By diluting and weakening his solvents so as to bring them as near as possible to the strength of the dissolving agents at the command of the plant, the chemist now endeavours to *estimate* the amount of *available* plant-food in a soil. In this way he is able to obtain information of undoubted value. Yet it is merely an *estimate*, and in practice has to be followed with caution. Data, however, are being gradually accumulated on these lines which will eventually place the inferences to be derived from soil analysis on a far more useful basis than formerly existed.

Evidence of the Crops.—Recognising the difficulty of accurately estimating the fertility of soil by analysis, Georges Ville, the eminent French chemist, recommended the more elaborate and more reliable plan of testing the soil by the “evidence of the plants themselves.” He says:—

“I laid down the principle that by means of four substances—phosphoric acid, potash, lime, and nitrogenous matter—it was possible to bring the most barren soil to the highest degree of fertility. We have learnt more than this—viz., that these four substances, however efficacious they may be, only remain so as long as they are associated and united one with the other; for by suppressing one, the remaining three are often rendered inert, and frequently lose the greater part of their activity.

“We have further said that these four substances are not of the same degree of utility to all descriptions of plants, but that each has a preponderant or subordinate action by turns; that for cereals, colza, and beetroot, nitrogenous matter

was the preponderant constituent; phosphoric acid fulfils a similar function with respect to maize, cane-sugar, and swedes; whereas potash preponderates in the case of potatoes and leguminous plants. If you thoroughly understand these three fundamental propositions, you will readily see by what natural deductions we shall be able to found upon them a practical method of analysis that will be accessible to all.

“Suppose, for instance, that we experiment upon the same soil with five different manures: first of all, a manure composed of the four substances of which we have been speaking, and to which we have given the name of normal manure; and next with four manures composed of three ingredients only, excluding in rotation nitrogenous matter, phosphoric acid, potash, and lime, and with these produce a parallel series of crops—

With the normal manure.		
Manure without nitrogenous matter.		
"	"	phosphates.
"	"	potash.
"	"	lime.
The soil without any manure.		

The result will be that the complete manure produces 43 bushels of wheat per acre; manure without nitrogenous matter produces 14 bushels; manure without phosphates, 26½; manure without potash, 31; manure without lime, 41; and the soil without any manure, only 12 bushels per acre.

“The conclusion is evident and conclusive. The soil requires, above all, nitrogenous matter; it is provided with lime, but insufficiently supplied with potash and calcic phosphate. What analysis, I ask, be it as delicate as it is possible to conceive, will ever be able to furnish us with a series of results like this? According as the crops obtained with the incomplete manures differ from or resemble those resulting from the use of the normal manures, the conclusion we arrive at is, that the soil lacks the ingredient excluded from these manures, or *vice versa*.

“But this is not all. In every soil there are two portions to be considered—the surface soil and the subsoil, the upper and under layers—and it is most important that we should have definite

ideas upon this subject. We may gain the necessary knowledge very easily by substituting for wheat some tap-rooted plant—beetroot, for instance, which buries itself in the ground to a much greater depth.

"With potatoes, the information gained is no less instructive and precise:—

	Crop per acre of Potatoes.	
	tons.	cwt.
Normal manure . . .	11	3
Manure without lime . .	8	4
" " phosphate . . .	6	6
" " nitrogen . . .	5	18
" " potash . . .	2	2
Soil without manure . .	2	14

The potato, then, tells us that the soil of Vincennes does not contain sufficient proportions of potash and of nitrogen; and if it shows a preference for soil that is rich in potash, it is because that substance is its dominant constituent—that is to say, it is the ingredient in manure that acts most beneficially upon that special crop.

"The evidence of these two plants is not contradictory but confirmatory, and you will observe how the preponderance of certain constituents gives an additional value to the same facts. In order to gather an exact idea of the richness of the under layer or subsoil at Vincennes, it is necessary to consider the result which was obtained at the same time with wheat and potatoes. A series of crops of wheat shows plainly that nitrogenous matter and potash are present in restricted proportions, and a series of potato crops confirms and ratifies this testimony; only with manure without potash, the crop of potatoes is feeble and comparatively smaller than that of wheat, because potash is a dominant constituent in potatoes, and only a subordinate constituent in wheat.

"Here, then, is a perfectly accurate system of experiments, and the information gained may at once be applied to practical use. With an experimental field we always determine the nature of the substances useful to plants contained in the soil, and also determine in what constituents the soil is deficient, and with this knowledge we can decide what sort of manure it will be advisable to employ.

Method of Test Experiments.—"I will briefly show you how we should proceed in the formation of such fields, according to the purpose for which they are to be used. If the results of our experiments are somewhat important, we must choose a piece of land representing the mean fertility of the whole estate, and divide it into ten plots, each containing, say, a quarter of an acre, to be fertilised, as shown beneath:—

No. 1	is to receive 24 tons of farmyard manure.
" 2	" 12 " "
" 3	" very rich normal manure.
" 4	" ordinary "
" 5	" manure without nitrogenous matter.
" 6	" manure without calcic phosphate
" 7	" manure without potash.
" 8	" manure without lime.
" 9	" manure without mineral matter.
" 10	" soil without any manure.

Here is a system equal to all the exigencies of every kind of culture. Thanks to this method of growing crops side by side, we are able to follow methodically the exhaustion of the soil: that advanced-guard of the field of experiments indicates with certainty the precise moment when the soil is ready to receive nitrogenous matter, potash, or calcic phosphate, as the case may be.

"But it will be said that on every farm it may happen, as it nearly always does, that there are soils of very different nature. The experimental field, of which we have just been speaking, does not suffice for an extended inquiry, and in order to arrive at useful results, it is necessary to set aside an additional quarter of an acre, divided into four parts, on which to experiment with these different manures: normal manure, mineral manure, and nitrogenous matter, the fourth part receiving no manure at all.¹ With these four combinations of manure, under the condition that if necessary the trial may be repeated, we can acquire

¹ The best arrangement as to experimental plots in fields is to select so many drills if the crop is roots, or so many ridges or yards wide if corn or pasture, so that each plot may run from end to end of the field, and thus, as far as possible, embrace all the variations in the character and condition of the soil.

with certainty all information of which, practically speaking, we have need. The first field, by reason of its greater extent, and the more numerous and varied combination of manure that it receives, is, as it were, a centre towards which all the others must gravitate. The results given by the smaller plots are tested by those of the first field, which acts as a sort of touchstone, and in a certain measure completes and rectifies their signification. When you are once familiarised with this mode of investigation, every kind of culture becomes a source of information concerning the state of the soil—its richness or its exhaustion. Here, for instance, is an example:—

“On two contiguous portions of land, say of a few square yards, sow peas and wheat without any kind of manure. This little experiment will amply suffice to ascertain if the soil contains nitrogenous and mineral matter. We have already seen that nitrogenous matter was the dominant constituent in wheat, and that it was only of very secondary importance to peas, if indeed its action could be regarded as of any use at all to them; whilst the dominant constituent in peas was potash. You see now, by the light of these simple facts, with how much importance the experiment just quoted can be invested. If the two squares of wheat and peas are equally fine, it proves that the soil contains a sufficiency both of nitrogenous and mineral matter.

“Now, if the wheat becomes small, yellow, and rather soft, whilst the peas flourish well, it proves that the soil is lacking in the dominant constituent of wheat, which is nitrogenous matter, whilst it contains, on the contrary, a sufficiency of mineral matter, and above all of potash.

“We will extend the range of our observations. Lucerne has roots which penetrate deeply into the subsoil. It is from these under layers that it principally obtains the mineral matter, of which it requires a large quantity. Suppose that lucerne prospers whilst peas are weakly. What are we to conclude from this? That the superficial layers of soil are lacking in potash and phosphates, whilst the deep layers are provided with them; but if the two plants progress equally well, we know that the superficial and

deep layers of soil are well provided with mineral matter.”¹

Farmers' Experiments.—Mr F. J. Cooke, Flitcham Abbey, Norfolk, in a paper read before the London Farmers' Club, on March 25, 1889, urged farmers to make trials upon their own land as to the kinds and quantities of manures best suited to their farms. He stated that he had been doing so himself annually for some twenty years, and he was not aware of any other separate practice which had been so useful to him. The information he thus obtained had saved him much unprofitable outlay on manures which had formerly been unnecessarily or imprudently applied.

Mr Cooke's method of testing the wants of the soil and the crops is quite simple, and similar to that recommended by Ville,—namely, the use of the four necessary elements of plant-food—nitrogen, phosphoric acid, potash, and lime—*separately* and together, and as far as possible in the most economical forms,—one plot remaining unmanured, another having all the ingredients, whilst upon the other plots each ingredient is in turn omitted.

An interesting example of the value of experiments in discovering the manurial wants of separate farms, and of the unreliability at that time of chemical analyses of soils for this purpose, is given by Mr Cooke. A dressing of 3 cwt. of nitrate of soda and 3 cwt. of superphosphate was applied to a plot of barley at Flitcham, upon which the crop failed. An adjoining plot got these manures, and in addition 2 cwt. of muriate of potash, and produced 54 bushels of barley per acre. Yet the soil of both the plots was found by chemical analysis (by the only method of analysis then in use) to contain as much potash in the top foot of it as would be found in 3 tons per acre of muriate of potash. There was an abundance of potash in the soil, but it was not available to the barley. Hence, on this soil an application of potash was essential for profitable cropping, and no amount of other manures would succeed without it.

Analyses of these same soils, or similar ones in the same neighbourhood since

¹ *Artificial Manures.* G. Ville, 176-183.

conducted on more modern lines, have, however, been found to give indications corresponding to the effects noted by actual manurial trials.

All this tends to show not only the importance of, but also the difficulties involved in, the question of manures and manuring. In arranging the dressings of manure to be applied, the farmer must consider the probable contents and condition of the soil, as well as the wants of the particular crop. He will endeavour, as fully as possible, to utilise the "reserve fund" of fertility in the soil, and aim in particular at having the crop provided with a supply of plant-food, which will not only be ample in quality, and present in an available form, but likewise contain in *due proportion* all the essential elements of plant nutrition.

Law of Minimum.—This due proportioning or balancing of the elements

of fertility is a point of the utmost importance. It is illustrated by what is known as Liebig's law of minimum. Every soil contains a maximum of one or more, and a minimum of one or more, of the ingredients necessary for plant growth. Now the growth or produce of the plants on this soil is governed not by the combined quantity of all the ingredients present in the soil, but by the producing power of the essential ingredient present in the smallest proportion, no matter how small a part this deficient element may play in the economy of the particular crop. Again, let it be remembered that the strength of the chain is governed by the weakest link.

The object of manuring is to provide against deficiencies of this kind, and at the lowest possible cost to furnish the crops with a full supply of readily available well-balanced wholesome plant-food.

FARMYARD MANURE.

In a description of the various commodities employed as manure, the first place naturally falls to *farmyard dung*. At one time the only kind of manure available, it is still, in this connection, the mainstay of the farmer. Its pre-eminence is gradually lessening, yet it will always be an important agent in maintaining the fertility of the farm. There are now many farmers who depend more largely upon artificial manures than upon dung. Upon the whole, however, "muck" is still the staple manure, and artificial fertilisers merely supplementary to it.

Variety in the Quality of Dung.—Farmyard manure consists of the solid and liquid excrements of farm live-stock, and of the litter provided to them. Except when made and kept wholly under roof, it also contains a considerable quantity of rain-water. Its manurial value depends upon the class of animals by which it is made, the age of these animals, the kinds and quantities of food supplied to them, the kind and quantity of litter employed, and the manner in which the manure is made and managed generally—whether well trodden, evenly

mixed, the fermentation kept duly in check, and waste prevented.

TREATMENT OF FARMYARD MANURE.

Losses from Want of Care.—Farmers as a rule are not nearly so careful in the treatment of farmyard manure as they ought to be. It would be impossible to form any accurate estimate of the loss entailed annually by want of proper attention to both solid and liquid manure, but it is well known to be enormous.

Voelcker and Hall,¹ reviewing the chief experimental work done on the subject of loss of nitrogen in making and storing dung, at Rothamsted and Woburn, and by numerous foreign investigators, such as Maereker, Schneidewind, Wagner, Müntz, Girard, Gay, and Dupont, conclude that a great loss of nitrogen inevitably occurs in dung-making over and above the proportion re-

¹ "Valuation of Unexhausted Manures," by Voelcker and Hall, *Journal of the Royal Agricultural Society of England*, vol. lxiii., 1902, pp. 76-114. Also published separately (J. Murray), price 1s.

tained by animals from their food. Of all the nitrogen in the original food and litter, probably 15 to 18 per cent is necessarily lost in the process of making the manure, while a like amount is probably lost in storing it. This gives a total loss of original nitrogen amounting to 30 or 40 per cent under good and careful management. Under bad management this loss will be much increased, so that the scope for care and economy is wide. Professor Wood has recently shown that rich cake-fed dung is liable to greater loss by fermentation than poor dung.¹ The loss arises largely by the washing away of valuable elements of plant-food in rain-water, but more perhaps by the escape of volatile nitrogen, either in the form of ammonia, or—which is probably a very serious item—in the form of free nitrogen. Serious loss of nitrogen is caused by what is known as “fire-fang.” The dung-heap with its rich store of costly plant-food is too often left to look after itself. The heat may be burning out of it by “fire-fang,” or its life-blood, so to speak, passing away in a black streamlet, or disappearing in the atmosphere—all for want of thoughtfulness and thrift, and a little timely work on the part of the farmer and his men.

But this is not all. Over and above these there are losses of a negative kind, on account of which the amount of manure made upon many farms is much less than it might otherwise be. Some careful farmers lose no opportunity of adding to the manure-heap any sort of waste material, earthy or vegetable, which is capable of there becoming useful manure. They thus not only conserve what is already in the heap, but sensibly increase its bulk and value; while there is the further pleasing advantage in this careful system that where it is pursued the steadings are kept clean and tidy, the roadways and footpaths in and around it dry, comfortable, and free from mud and loose straw or other litter. Others again never seem to think that any effort should be made to assist the live-stock in adding to the contents of the dung-pit. Those who are thus neglectful not only lose useful manure,

but also have the thoroughfares in and around their steading constantly in an untidy and uncomfortable condition.

Nitrogen Annually Lost from Dung.—It was calculated by M. Grandeau that the value of the farmyard manure produced annually in France was £66,000,000, and that more than one-sixth of its most valuable constituents, equal to £11,000,000 a-year, is absolutely lost by faulty and careless management in the making and handling of the dung. Dr Bernard Dyer arrived at the conclusion that the annual production of farmyard manure in the United Kingdom amounts to some 40,000,000 tons, worth, at 5s a ton, as much as £10,000,000 sterling; and he adds that the probable annual loss of nitrogen alone by the careless treatment of this dung is as much as would be contained in from 230,000 to 340,000 tons of nitrate of soda, costing, at £10 a ton, from £2,300,000 to £3,400,000 per annum.² A very large proportion of this loss Dr Dyer thinks could be saved, and, in his opinion, the best way of attaining this end would be the universal use of deep-feeding boxes and covered courts—a system, however, that is not easily carried out where there is comparatively little straw available for use as litter.

But from all points of view the treatment of farmyard manure is a subject that demands and will amply repay the most careful consideration and attention.

Carting out Manure.—The carting of dung to dunghills in the fields in winter is not now pursued so largely as in former times. Better provision in covered courts and prepared dung-pits is now made for storing the dung at the steading. The winter carting of dung of course lessens spring work, which is an important consideration. The fertilising value of the dung, however, can be most effectually conserved by retaining the dung in the court or dung-pit at the steading till it can be spread on the land.

In some cases the dung, towards the close of winter, will have accumulated so high in the cattle-courts as to become nearly level with the feeding-troughs, thereby making them inconveniently low

¹ *Journal of Agricultural Science*, ii. 207.

² *Dyer's Fertilisers and Feeding-Staffs*.

for the cattle. To avoid such inconvenience it is still the custom in many parts to have the dung removed, and formed into dunghills in the fields intended to be manured in the ensuing season. The most convenient and proper time to do this is when the frost, snow, or rain prevents the ploughing of the land.

Different kinds of Dung for Different Crops.—In carting out manure at this time care is taken to have the dung placed upon or convenient to whichever field or division of field it is to be applied. Some farmers have considered it desirable to keep the different kinds of dung separate, so that each may be used for the crop for which it is best adapted. It is well enough known that the different sorts of farmyard manure—stable, cow, and pig—are not equally suitable for all kinds of crops.

But with the choice of several kinds of cheap and efficient artificial manure, the advantages of keeping the different sorts of dung separate are now of less importance than formerly.

Mixing Dung.—The better plan is to have all the kinds of dung mixed together as they are taken away from the various classes of stock. Thus, the horse-manure should be daily and systematically spread over the cattle-dung in the cattle-court or manure-pit. If horse-dung is left by itself in a heap, it will speedily get injured by "fire-fang." Then, it is also well to have the manure made by cows and store cattle mixed with the richer manure made by cattle which are being fattened.

Position of the Dunghills.—Another matter which deserves consideration before courts are begun to be cleared in winter, is the position the dunghills should occupy in the field. This point is determined partly by the form which the surface of the field presents, and partly from the point of access to the field. It should be a general rule that the dunghill should be placed in the field where the horses will have the advantage of going downhill with the loads from it when the manure is applied to the land. Wherever practicable, this rule should never be violated, as facilities afforded to labour in the busy season are of great advantage.

If the field has a uniformly sloping surface, the dunghill should be placed at the highest side; but the access to the field may only be at the lowest side, and it may be impracticable to reach the highest side by any road. In such an untoward case the loads should be taken to the highest side, up a ridge of the field, and frosty weather chosen to form the dunghill in it, as the cart-wheels and horses' feet will then have firm ground to move on. The loss of time thus incurred by the distant travel will not be much felt in winter. But if it be impracticable to lead dung there, on account of the soft state of the land or steepness of the ascent, the only alternative is to form the dunghill at the side nearest the access.

When the field has a round-backed form, the dunghill may be placed on the top of the height, to allow the load to go downhill on both sides—in all cases certainly where the manure is to be put out in heaps, with a heap in every third drill, each heap about three or four yards apart. But when the manure is to be thrown from the cart in graipfuls as the horse moves along the drill—which is by far the most expeditious method—some consider it a better plan to have the dunghill at the lowest end of the field, so that as the cart goes up the hill, it always becomes lighter until it arrives at the top, by which time the cart will be empty. This is the best system to pursue, where the land is flat enough at the entrance of the drills to allow a horse to draw easily a full-loaded cart. If this cannot be done, it is better, as already suggested, to empty downhill.

To form a proper site for a dunghill, a head-ridge should be formed along the crest of the height when the stubble is ploughed. In a level field, it is immaterial which side the dunghill occupies.

The precise spot which a dunghill should occupy in a field is thus not a matter of indifference. We have seen a dunghill placed in the very centre of a field which it was entirely to manure. From this point the carts must either go across every ridge between the one which is being manured and the dunghill, or go direct to a head-ridge, and thence along it to the ridge to be manured. This latter alternative must be adopted if the

dung is to be deposited in drills; and if not followed, the drills prepared for the dung will be much cut up by the passage of the carts across them—a practice never to be allowed when neat work is desired.

The proper position for the dunghill is on a head-ridge, or at the end of a side-ridge of the field. Some prefer the end of a side-ridge, because the length of a dunghill upon a head-ridge prevents the ends of the ridges opposite to it being ploughed or drilled to their proper length. The dunghill on a side-ridge only prevents that single ridge being ploughed to the last.

When a large field requires two dunghills, the one first to be used should be placed *along the end of a ridge* at such a distance from the far side of the field as that the ridge occupied by the dunghill may be ploughed when the manuring reaches it. The second dunghill should be on the nearest side-ridge. The first dunghill should be first used, for the farthest side of the field.

Should the weather be fresh and the ground soft, one dunghill may be made on the side-ridge nearest the gateway, and made large enough to manure the whole field. A large dunghill in one place will doubtless take more time to manure the field at the busy season than two dunghills at different places; but, in soft weather and soil, it is better to incur a little future inconvenience in good weather, and on firm soil, than make the horses drag half-loads axle-deep along a soft head-ridge.

The main objects to be kept in view, in selecting the sites of dunghills in the field, is to ensure that the loads in the busy season will not only have a passage downhill, but that the dung will be situated at the shortest distance from the place where it is wanted, and that the ploughed or drilled land may not be injured by cart-wheels and horses' feet.

When it is considered desirable to go through a part of the prepared land on the way from the dunghill to the drills, it is a good plan to draw six or eight drills for a road, following as easy an incline as possible. This prevents the treading of the surface-soil by the horses and carts.

Fields to be Manured.—The fields

in which dunghills are usually formed are those in which, in the ensuing season, are to grow the green crops. The potatoes coming first in order, the land for them should first have its manure carried out and formed into a dunghill—that is, if it is decided to cart the manure into dunghills. The mangels and turnips come next. All the dunghills should be respectively of such a size as to manure with a given quantity the extent of land to be occupied by the particular crop.

Loss of Time in Carting Dung.—Few would believe the care required in laying straw in a court, except those who have experienced the trouble and loss of time incurred in removing dung from it, when the straw had been carelessly laid down. The courts are usually cleared during frost, when time is regarded of less value—the plough being rendered useless; but notwithstanding this common feeling, a loss of time at this season may cause a serious loss of it in a future operation.

For example: The hard state of the ground may favour the carriage of manure to a distant field, to gain which most of the time is spent upon the road. Suppose frost continued as long as to allow time to carry as much manure as would serve the whole field, provided ordinary diligence were used on the road, and no interruption occurred in the courts. Suppose, further, on manuring the field in summer, there was found to be less manure in the dunghill, by a small quantity, than was wanted, and that half a day, or, at most, a whole day's driving in winter, from the steading, would have supplied the requisite quantity, it is clear that one day's driving could have been accomplished in frost at much less loss of time than at the season when the manure is wanted. Any sacrifice of time *must* be made on the instant, or the field will be deprived of its due proportion of manure.

This is no hypothetical case; it has occurred in every farmer's experience. Now, what was the primary cause of this dilemma? Either too much time had been spent upon the road in driving the manure, or interruption had been experienced in the courts. To which of these two causes ought the waste of time

to be probably attributed? With regard to driving, farm-horses get into so regular a pace upon the farm-road, at all times, that little loss or gain of time can be calculated on their speed. Besides, when a number of carts are employed at any work, each cart must keep its turn, otherwise it will be overtaken or left behind by one of the other carts.

Careless Strewing of Litter in Courts.—The probability is, the loss of time was incurred in the courts, and the reason was this: The usual way of taking the wet litter from the work-horse stable is to roll as much of it together with a graip as a man can lift, and throw it into a barrow, in which it is wheeled into a cattle-court, emptied on any spot to get quit of it in the shortest time, and left in heaps to be trampled down by the cattle. Bundles of thatchings of stacks, not always dry, are carried into the court, and put down anywhere and partially spread. Long straw-ropes from the stackyard are pulled along the court.

In doing all this—at intervals of time—it seldom enters the head of any one to do what would facilitate the lifting of the dung-straw afterwards, when the court is being cleared of its contents. When that time arrives, and before the litter has become short by fermentation, the difficulty attending its removal is then experienced. A lump of long damp straw is seized by one part of a graip, while the other part of it goes into a coiled-up heap of straw-rope, which cannot be torn asunder without much exertion on the part of the ploughman, pulling it this way and that. Another graip encounters a long straw-rope, which, after much tugging, is broken or pulled out, and thrown upon the cart with its end dangling down.

In short, not a single graipful is easily raised, and the work is not expedited when a heap of chaff intervenes and evades the thrust of the graip. Add to this the few hands generally sent to assist the ploughmen to fill the carts, and some idea may be formed of the waste of time incurred at this necessary work. The men are not intentionally idle, and when they are put to it they work very hard; and yet, in such circumstances, they show but small result from unwonted exertion.

How Litter should be Spread in

Courts.—Thus, much time is uselessly thrown away which would have been saved had the litter been spread judiciously over the surface of the dung-heap, and had the straw-ropes from the stackyard been cut into short pieces. Free from such unnecessary obstructions, a whole day more of driving of dung might have been obtained ere frost gave way, which would have avoided the dilemma experienced at the manuring of the field.

The effectual way of preventing delay in carrying out dung to the dunghill in the field is at first to put down the litter so as to be easily lifted afterwards, and to afford as much assistance at filling the carts in the court as to detain the horses for the shortest time.

The litter should be laid down at first, and continued to be so, in this manner. The bare ground in the empty court should be covered evenly with straw, and the future layers of litter should be spread thinly, beginning at the end of the court farthest from the gate. The litter should be spread with the slope of its lower part towards the gate, and carried gradually forward every day until it reaches the gate; and every kind of litter, whether from the work-horse stable, the stackyard, or straw-barn, should be intermixed and treated in the same manner.

The straw-ropes should be cut into small pieces and thrown about, and the chaff not fit for fodder sprinkled, and not laid in heaps. Thus layer above layer is scattered, until the whole season's manure is made.

Another very important reason why litter should be evenly and carefully spread over courts or heaps of dung, will be explained in speaking of "fire-fang" in farmyard manure.

Chaffing Litter.—An effective method of avoiding the losses arising from the uneven spreading of long litter on manure-heaps and in courts, is to have the litter cut short by a litter-cutter. The advantages of this practice will be referred to in Vol. III. in dealing with the management of cattle in houses.

Emptying Courts of Dung.—When the time has arrived for emptying the courts, the process is *begun at the gate* through which the loaded carts are to

pass, and the dung lifted from there will come up in sloping layers, having an inclination to the top of the dung-heap, not in entire layers of the whole depth of the dung-heap, but in successive small detached layers, one beside the other, and succeeding one after the other, from the gate to the farther end of the court. The empty carts enter the court by another gate, if there be one, and, without turning, take up their position where the loaded cart was before, and has just passed through the gate appointed for it.

When there is only one gate to a court, and the court not very large, and the lot of beasts obliged to be kept in it, for want of room to put them elsewhere, one cart, on starting work for the day or yoking, may have to wait on the outside until the other has been loaded and gone away.

When the court is large, it may be possible to load two or three carts at one time.

On dropping work at mid-day, it will save time, at starting again after dinner, to fill a cart and allow it to stand loaded, without the horses, until the time for yoking, when the horses are put to, and it forms the first load to start for the field,—the work being so arranged that only one cart is at the court at one time.

On clearing a court, or any part of it, it should be *cleared to the ground*; because the manure made from a dung-heap that has been simultaneously formed will be more uniform in its texture than that made from a heap composed entirely of new dry straw on the top, or of old and wet straw at the bottom. Indeed so important is this point of having the old and the fresh dung mixed, that to ensure it many farmers turn over the entire dung-heap before it is carted out.

Besides, it is much better for the future comfort of the cattle that the court receive a fresh dry littering from the bottom than that the wet bottoming should remain.

Turning Dung. — But this turning should not take place except within eight or ten days before the dung is to be applied to the land. The turning sets up a rapid fermentation, and if this fermentation is allowed to go too far, the dung will be seriously injured.

Cattle sometimes are injured by a cart or horse when the court is emptying; and, to avoid the risk, they should be confined in the shed as long as the people are at work in the court.

Art in forming a Dunghill. — To form a dunghill in the field requires some art. A dunghill having a breadth of 15 feet, and of four or five times that length, and of proportionate height, will contain as much manure as should be taken from one spot in manuring a field quickly. Suppose that 15 feet is fixed upon for the width, the first carts should lay their loads down at the nearest end of the future dunghill, in a row across the whole width, and these loads should not be spread thin. Thus, load after load is laid down in succession upon the ground, maintaining the fixed breadth, and passing over the loads previously laid down. On frosted ground the bottoming is easily formed.

After the *bottom* of the dunghill has been formed of the desired breadth and length, a gradual slope upwards is made from the near end and carried to the highest level near the farthest extremity, from which also a slope descends to the end. Thus layer after layer is laid on until the full height of the dunghill has been reached, the dung in the meanwhile being trampled down by the carts and horses. The slope towards both ends facilitates the passage of the carts in going on and coming off the dunghill.

Every cart-load laid down above the bottom stratum is spread around, to mix the different kinds of dung together, in order to give a uniform texture to the whole heap of manure. To effect this purpose the better, a field-worker should be employed to spread the loads on the dunghill as they are laid down, ploughmen being apt to spread it too little, and the field-worker will save the time of both men and horses. It is essential to have the whole dunghill equally compressed, with a view to making the manure of similar texture throughout.

If the manure is being carted from a dungstead at the farm, containing a large proportion of manure from the cow-byres, it may be too soft to enable the carts to go on it as recommended above. In such a case a row of carts should be emptied across the bottom of the proposed dung-

heap, the rest of the manure being thrown from the carts by the graips on to the top of what was emptied up, until it reach the desired height, perhaps 3 to 4½ feet.

After the dunghill is completed, the scattered portions of dung along the sides and the thin extreme ends should be thrown upon the top and trampled down, and the entire top brought to a gentle ridge, like a house-top, so that heavy rains may be run off, instead of soaking down through the whole mass. Such a finishing to a dunghill is very generally neglected.

Preventing Fermentation.—The object aimed at by the compression of the dunghill by the loaded carts is to prevent immediate fermentation. So long as the temperature continues at its average degree in winter of 45°, there is little chance of much activity of heat in the interior of a dunghill; but towards spring, when the temperature rises, it will show symptoms of action. Even then, a temperature of 65° is required to commence the second stage of fermentation. The first fermentation only evaporates the water, the destruction of fibre commencing with the second stage of fermentation.

Covering Dunghills.—Covering a dunghill in the field with a thick layer of earth, with a view to exclude the air and check fermentation, is a useful precaution and also serves to throw off rain. In some cases loose sheets of corrugated iron are used to carry rain-water off dunghills.

A dunghill, made up in a loose manner at once in graipfuls from each cart-load, gives, in effect, the dung a turning, and although covered with earth, it soon becomes fermented enough for an early crop, such as beans; but if it is not to be used until an advanced period of the season, when the temperature will have risen considerably, loose dung will ferment too rapidly.

Methods for Preserving Nitrogen in Dung.—Investigations made by Holdeffleiss of Proskau have demonstrated the value of certain simple expedients for preventing the loss of nitrogen by over-fermentation. The simplest of these remedies is to make, as a foundation for the dung-heap, a good bed of dry earth,

and to remove the dung as frequently as may be possible from the floor of the yards or boxes, and to pile it on the bed of earth, covering it occasionally with a light protective layer of earth, and, finally, with a good thick coating of the same material. Dung, preserved in this way, was found by analysis, after six months, to have lost but 2 per cent of its virtue; while a similar mass of dung, without the protective cover of earth, lost 23 per cent, or nearly one-fourth of its virtue, measured in each case by the loss of the most valuable ingredient, nitrogen. Tested in the field, the earth-preserved manure yielded on a potato crop more than three times the increase given by a corresponding quantity of the carelessly kept dung unprotected by earth, and in another trial nearly twice as much increase on a wheat crop. This mode of preservation is particularly recommended on strong moisture-retaining land.

Other methods of preservation described, less simple, but nevertheless easy to carry out, are to sprinkle the dung, as it is produced, with ingredients, which, like superphosphate and gypsum, shall act as fixers or absorbents of ammonia; or which, like kainit, shall act as antiseptics, or preservers of the dung from speedy fermentation. The former produce a fairly ripened manure, suited to dry climates, or to clay soils poor in humus or organic matter; while the latter are recommended for the preservation of dung for light and open land, where it is desirable that it shall remain "long" or unrotted. If the former method of chemical treatment be adopted, a mixture should be made of equal parts of superphosphate and gypsum, and about 1½ lb. or 2 lb. a-day, per head of stock, should be sprinkled amongst the dung. If, on the other hand, kainit be used as an antiseptic, about 2 lb. per head per day should be strewn on it.

The immense superiority of manure prepared in either of these ways to manure heaped without these precautions has also been proved not only by analysis, but by experiment in the field. The details of these experiments of Holdeffleiss are duly set forth in the article already referred to, and are very striking.

Preservation by earth, where good

loamy soil is at hand, appears to be the simplest method; but on clayey farms, during wet weather, friable earth is not easy to obtain, and then probably superphosphate or gypsum, for the time being, may be used as directed.

The story of the sad waste of farmyard manure by deterioration in the yard and on the heap is an old one; and the recommendation to mix earth with it, and even to mix superphosphate, gypsum, or kainit with it, with a view to lessening the loss, is far from new.

What was, however, new and striking in the experiments of Holdseleiss is the quantitative demonstration of the nature and extent of the saving effected, as shown by accurate weighing and measuring and analysis of each heap, treated and untreated; and the corroboration of this by the relative action of the manure on farm crops, observed not merely on the crops to which it was immediately applied, but on those of a succeeding season.¹

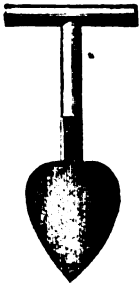


Fig. 337.—
Dung-spade.

Dung-spade.—The dung in hammels and courts is often so much compressed as almost to resist the entrance of the graip. To enable it to be easily lifted, therefore, it may in this case be cut in narrow parallel divisions with the *dung-spade*, fig. 337. This consists of a heart-shaped blade of steel, thinned to a sharp edge along both faces; and its cross-head, or helve, fastened to it with nails into a split socket. The height of the spade is 3 feet, length of the cross-head 18 inches, length of the helve 18 inches, length of the blade 16 inches, and its breadth 10 inches. It is sharpened with a scythe-stone.

In using this spade, it is raised with both hands by the cross-head, and its point thrust with force into the dung-heap, up to the head of the blade at least, making a rut across the dunghill by a repetition of thrusts. The blade is heart-shaped, not square like a common spade, because, when cutting the

dung-heap to a greater depth than the length of the blade, its rounded ears escape catching the dung on the blade being drawn up.

Another instrument for cutting dung is like the common hay-knife, and used in like manner, but is not so efficient an implement as the spade. The common spade used in cutting surface-drains, well sharpened, is used by many farmers for cutting dung.

Manure-court.—It is the practice of many farmers to keep the dung from the cow-byres in a loose state in a dung-court, enclosed with a strong wall 3 or 4 feet in height, into which the dung is wheeled as it comes from the byre, a plank being used as a roadway for the barrow to ascend, the dung being allowed to accumulate here till required on the land. It does not need any more turning, and soon gets in a state fit for potatoes or turnips. This plan saves the trouble of turning the dung, and if a roof were provided to the pit, loss by washing would be prevented.

Is Winter Carting-out Injurious to the Dung.—As to the influence which the carting out of dung to heaps in the field in winter has upon the manure there is some difference of opinion. Some contend that the carting process entails loss by volatile ammonia passing away in the atmosphere, and by rain-water washing away valuable ingredients. The danger of this, however, is reduced to a minimum, if not altogether removed, by proper care in forming and finishing the dunghill. If the dunghill be well packed in the field and finished off on the top—by being raised in a ridge along the centre and covered with a smooth layer of earth—so as to keep out rain-water, the risk of loss is diminished.

Upon the whole, therefore, the carting of at least a certain quantity of the dung to the fields in the slack months of winter has several points to commend it. With proper care it may be done with safety to the manure, and there is great advantage in the saving which is effected in the carting in the busy spring-time.

Field-sheds for Manure.—To protect the dunghills it has been suggested that permanent sheds might be erected at convenient points in the various fields, to which the dung could be

¹ Dyer's *Fertilisers and Feeding-Subs.*

carted in winter as usual. The great expense involved renders this plan impracticable, except, perhaps, in a few rare instances. In the third edition of this work the following sketch was given of a shed for manure, which might answer in any part of the fence of a single field, or in the point of section of two fences in the corners where four fields meet. Fig. 338 is such a place, where there is a shed, 80 feet long and $12\frac{1}{2}$ feet broad over walls, standing either E. and W. or N. and S., whichever is most convenient for the dung to be brought from the steading to the corners of the four fields, where are the midden-stances, 18 feet wide

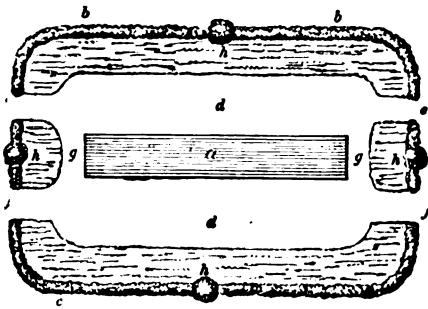


Fig. 338.—Dung-pit for four fields.

- a Shed.
- b b Fences of 2 fields.
- c c Fences of 2 other fields.
- A Points where the fences of 4 fields come.
- d d Midden-stances.
- e e Outlets to 2 fields from their midden-stance.
- f f Outlets to 2 other fields from their midden-stance.
- g g Passage at the ends of the shed.

each, upon which the dung is first put when taken out of the courts early in winter, but if towards the end of winter it should be put into the shed at once.

As most of the dung experiences much warmth from a high temperature of the atmosphere before it is ploughed into the ground, a plantation, 12 feet in width, of spruce or Scots fir, around the midden-stances, would be a screen from the sun or a protection to the outside of the midden from heavy rains from any quarter in winter.

There are four slip-gates, 10 feet wide, for taking the dung in and out to the four fields. The midden-stances should be firmly causewayed or macadamised. Such an arrangement, shed, stances, and

fences, would occupy a space of 134 feet long by $84\frac{1}{2}$ feet broad, or about a quarter of an acre. The fences of the four fields meet those of the midden-stances at four points. There is a passage for carts at both ends of the shed.

Winter Industry lessens Spring Work.—We have dwelt the longer on the subject of clearing the courts of dung for the making of dunghills in the fields in winter with the view of enforcing the fact that farm-servants are apt to believe that work may be done at leisure during a stormy period in winter, on the supposition that time is of less value at that season than at any other. We have seen, on the other hand, that time uselessly spent in winter on one thing may cause much trouble and delay on another thing in the busy season of spring. Let, then, everything done in winter tend to facilitate and expedite whatever has to be done in the ensuing busy season; and for that intent, few things require more attention than the judicious distribution of litter in the courtyards.

Dunghills Injurious to Drains.—A rather curious and entirely unlooked-for effect took place from the ooziings of dunghills in two fields on the estate of Pumpherstons, near Midcalder, in the county of Edinburgh. Tile-drains that had been made in the autumn before the dunghills were formed were found to be choked in spring, and bursting out water. On opening them, the tiles within a limited space were completely filled with a peculiar substance. The subsoil in one field was gravelly, and the drains 3 feet deep; that of the other, clay, with drains of 20 inches deep. In both cases the drains leading from a dunghill were only so affected, and the conclusion arrived at was, that the ooziings from the dunghills had induced the growth of the substance found in the tiles. The substance was of a dirty grey colour, slimy, tenacious, some pieces of it resembling fragments of skin, but appearing to consist, when pulled asunder, of minute fibres, too fine to be easily observed by the unassisted eye. It had an extremely offensive, putrid, animal odour, and was impregnated with a good deal of earthy matter, which long washing with water could not entirely separate. It was pronounced by Dr Greville to be a

plant—the *Conferva bombycina*—the filaments of which are extremely fine, and act as a cobweb in catching and retaining minute insects, larvæ, and floating atoms of inorganic matter in water. These plants grow rapidly, and as rapidly pass into putrescence.

The moral of this is that no dunghill should be formed above tile-drains, for although in this case the alarming state of the drains was but of short duration, more permanent injury might be experienced from stronger materials. Anyhow, it is safer to avoid such inconveniences by placing dunghills beyond the reach of drains, and also making the sites of dunghills impervious to liquids. A side-ridge of a field is the safest place, and, when the dung is put into a pit, it is quite out of the way of doing harm. Drains of 4 feet deep would probably have been less injured, if at all, in being beyond the reach of oozing.

A shallow trench may be formed round the dung-pit (completed as described above) leading to a puddled hole at the lowest point. The black essence pressed and washed from the dung would gather in this hole, and might be from time to time thrown on the top of the heap.

Covered Manure-pits.

The important questions relating to fermentation in farmyard manure—its causes and effects, and how it may be regulated—have, from time to time, given rise to much interesting and intelligent discussion, and is to some extent discussed in other parts of this article.

Mr Rowlandson, of Bootle village, near Liverpool, writing in the *Journal of Agriculture* for October 1845, said: "The fermentation of manure-heaps depending upon the presence of heat, moisture, and the atmosphere, the skilful farmer will avail himself of the means in his power to promote or retard fermentation, by dispensing with or admitting one or other of these agents, as the case may require. This is done in several ways. The free admission of the atmosphere is one of the principal causes of excess of fermentation; and Boussingault, although he does not state this to be the cause, admits that 'it is of much importance that the heap be pretty solid, in order to

prevent too great a rise of temperature, and too rapid a fermentation, which is always injurious. At Bechelbronn, our dung-heap is so firmly trodden down in the course of its accumulation by the feet of the workmen, that a loaded waggon, drawn by four horses, can be taken across it without very great difficulty.'

"Notwithstanding this opinion of a man of science, many writers have asserted that tramping down manure is injurious. Each party is right according to circumstances. If a manure-heap is wanted for immediate use, a free admission of the atmosphere is necessary, to promote rapid fermentation; but this is done at the expense of a considerable escape of its volatile contents. On the other hand, if intended to lie for some months, as is frequently the case, pressure, and consequent absence of a current of atmospheric air, will retard fermentation.

The Manure-pit.—"By restricting the admission of air, we have a direct command over the fermentation of the manure-heap; and this restriction can be attained only by placing the manure in pits. The usual shape of a manure-heap is that of a cube or parallelopipedon, each being a figure of six sides, five of which are exposed to the influence of the atmosphere, the bottom only not being surrounded by it. By the pit we shall completely reverse the order, one side, the top, only being exposed to the atmosphere; and that is also the side, from the altered circumstances of the heap, into which the air will have the greatest difficulty in penetrating. In fact, from the absence of draught from the sides, fresh volumes of air will only penetrate the top by means of pressure. . . .

"Another advantage to be derived by using pits is, that in winter the caloric arising from the fermentation of the heap could not be dissipated so speedily, but would be diffused through the heap more equally than it is under the present system, when surrounded by a cold, perhaps a frosty, atmosphere. It is so well known that manure-heaps formed in winter do not ferment equally, or scarcely at all, that it has given rise to the axiom, that one load of manure

formed in summer is worth two formed in winter.

Oozing of Liquid from Heaps.—“The amount of my observation is, that in heaps, as usually formed, with free access to the atmosphere, a larger amount of humic acid, soluble in alkalies, is formed than when the manure is placed in pits, and access of the atmosphere is limited. In the latter case, some humic acid is formed; in both cases, the humic acid is in the same state as that which is found in barren mosses, as I have determined by repeated experiments. The humic acid has a strong affinity to combine with the alkalies, potash, soda, and ammonia in manure-heaps, and this forms the brown-coloured solution which is observed running from them after rain. It is perfectly obvious, therefore, that every drop of the brown-coloured liquid which oozes from the manure-heap contains, in combination, one or other of the above-named alkalies, two of which, potash and ammonia, are of so much importance as fertilisers. The mode I have suggested of placing the manure in pits may be said to remedy this evil, as, at all events, it will prevent the liquid from running away.”

It will be observed that these latter remarks apply to the dung-heap in a state of fermentation. When not fermenting, the dung-heap, in winter, parts with very little liquid; and if the top of dunghills in the field were finished off and covered with sheets of iron or with earth made smooth on the surface as already explained, little or no rain could get into the heap.

Manure-pits at Steadings.—Although the proposal to erect manure-sheds in the fields cannot be said to have come into practice, permanent manure-pits with substantial roofs have been constructed at many farm-steadings. This covered pit is situated as conveniently as possible to the cattle-courts and byres, and is sometimes round or oval, but as a rule square or oblong. Corrugated iron roofing is frequently used for this, and in some cases the side walls are not carried close up to—about 4 or 5 feet high, or 3 or 4 feet from—the edge of the roof, which therefore rests on pillars. The manure is conveyed into this pit in carts or barrows daily, or at intervals,

as may be considered best, or as may be most suitable to local circumstances.

But a preferable plan—except in northern districts, where the winter is long and idle and the spring short and busy—is to have the dimensions of the covered courts sufficient to admit of the whole season's dung being allowed to remain under the cattle until it is required upon the land.

Flooring of Manure-pits.—It is desirable that the bottom of the manure-pit should be made water-tight, so as to prevent the urine from passing into the earth. A layer of clay pounded firmly makes a good bottom, and is very often adopted. Concrete is very effective, but may be more costly. What should be done with any excess of urine will be explained presently.

Extra Value of Covered-court Dung.—There is less winter carting of manure to the fields now than formerly. With the extended introduction of covered courts, the practice of keeping almost all the season's manure under the cattle till required for the land has gained in favour. Upon very many farms the dimensions of the covered courts are now so extensive as to easily admit of this; and important advantages are claimed for the system. The spring work is of course increased by having the manure to cart from the steading, but it is contended—and the contention is supported by many eminent practical farmers, as well as by men of science—that this extra work in spring is far more than counterbalanced by the greater value imparted to the dung by its continuous good treatment under cover.

The question of the relative properties of manure made in covered courts and in open yards is discussed at page 161 of this volume, and what is said there should be consulted at this stage. As to the respective and relative merits and influences of dung which has been turned, and lying for a time in a dunghill in the open field, and dung taken direct from below the cattle in the covered court, there is some difference of opinion. It has in several cases been found in practice that the latter was the more efficacious for potatoes, and there is perhaps a preponderance of testimony in favour of carting direct from the covered court.

The Art of "Making" Manure.

Well-made Dung.—It is of course important that the manure should be "well-made"—a term sufficiently understood by farmers. It should be even in texture, with no lumps of fresh straw or of litter of any kind. Well-rotted dung will exert its influence more rapidly than rank fresh dung, and this is often a point of importance. Too often farmyard manure is estimated merely by its bulk. There could be no greater mistake. Far more important is the question of quality. The mechanical influence which bulky farmyard manure exerts in opening up a close soil is certainly of considerable moment. The chief function of the dung, however, is the supplying of plant-food. Its value is dependent mainly upon the amount of plant-food it is capable of providing; and in the estimating of this, it is the character rather than the mere bulk of the dung that has to be considered. One load of short, rich, well-rotted dung may be worth two of rank fresh dung in which there may be a good deal of straw but very slightly decomposed. There is little use of filling drills with rank fresh straw, in which it should be remembered there is little manurial value.

The Art.—There is therefore some art in having dung "well made." It lies mainly in this: Litter the court so as to provide every part of it with just as much litter as the animals can turn into well-soaked firmly packed manure. Spread the litter frequently, and in thin layers, taking care above everything that no dry bundles of straw can get buried in any part of the heap of dung. Depend upon it such dry bundles will become veritable volcanoes, burning up the valuable fertilising materials around them. If stable-dung is taken into the court, spread it evenly over the manure. If left in a heap by itself, it will be liable to injury by "fire-fang." The dung which is taken from the cow or other house in which there may be stalled cattle should also be carefully spread over the court, the wetter portions being thrown on the drier parts of the manure already in the court.

It is also desirable, as already indicated, to have the dung from cows and

store cattle mixed with that made by fattening cattle. The last will, of course, be richer than the two former, and it is well to have the dung-heap of uniform quality.

Pumping Urine on Dung.—Then, in the event of the farmer desiring as much straw as possible converted into manure, the cattle may be considerably assisted in this by having such of the liquid manure as finds its way into the manure-tank periodically pumped on to the mass of solid dung, the drier parts getting the larger share of the liquid. Where the supply of litter is sufficient, this is perhaps the best way of utilising liquid manure. By this method both the quantity and the quality of the dung may be greatly enhanced. Where litter is scarce, the animals may be able to moisten and make thoroughly all the material placed beneath them, without any aid from the liquid-manure tank. In that case, as will be presently explained, other uses will be found for the contents of the tank.

Injury from "Washing."—An argument used against covered courts is that the dung made in them is apt to be too dry. In open courts the rainfall no doubt helps the urine of the animals to make the litter *wet*, but the *wetness* which comes from the influence of rainfall may not be altogether beneficial. Indeed it has been well established by scientific investigation that dung is very liable to suffer serious injury by having its fertilising elements washed out of it by rainfall.

It is therefore desirable to note, that while moisture is essential to the successful making of manure, great damage may be done by having the dung exposed to washing. In open courts more harm is often done by the collected rain-water from roofs being allowed, through defective water-spouts at the eaves, to rush upon the dung with considerable force, than by the direct rainfall upon the area of the dung-heap. Indeed, if all the small quantity of rain which usually falls during winter would only distribute itself pretty evenly over the season, and descend in nice gentle showers, its influence upon the dung-heap might be all for good—that is, if the neglectful farmer would only give

up his careless ways and insist upon the water-spouts doing their duty. But winter rain is wilful, and too often falls in such torrents as to be perilous to the unprotected manure-heap.

It is thus, upon the whole, a good thing to have a roof over the manure, whether it be kept in the cattle-court or in a pit by itself. Do not attempt to convert more litter into manure than the animals, with the assistance of their own urine, can moisten and tread into "well-made" dung. Little reliance can be placed upon moisture from extraneous sources; and dung that contains any considerable quantity of straw merely rotted by rain-water cannot possess very high manurial value.

Mischief from Defective Water-spouts.—Incidental reference has been made to the neglect of water-spouts. Now this is a point seemingly small enough, yet of great importance. For be it remembered that through the absence of efficient spouts around the eaves to catch and carry away the water as it falls from the roof, the benefit of the roof over the manure may, as far as concerns rainfall, be almost entirely nullified. We have occasionally—even where substantial roofing had been thrown over the courts—seen the rain-water from the roofs allowed to rush upon the dung with all its concentrated force, thus doing much more harm than the same amount of rain would have done had it fallen directly and universally upon the manure. And all this mischief arose through neglect to repair a few feet of a decayed water-spout. Decayed water-spouts around the eaves of the cattle-court are like great holes in the farmer's purse, through which hard-earned coin steals imperceptibly away. For the sake of the manure we would rather have an entirely open court than the best covered court in the universe and no water-spouts to carry the rush of rain-water away from the dung-heap.

"Fire-fang" in Manure.—Much loss, all of which is preventible, is sustained through "fire-fang" in manure. Horse-dung is most liable to it, but it occurs in other kinds of manure where great neglect prevails. When stable-dung is thrown into a heap, and allowed to become dry, it will ferment in the centre,

and if left undisturbed, will rapidly pass into the most rampant stage of "fire-fang," which results in great destruction of plant-food. Bundles of dry straw, buried amongst cow-dung, may also become centres of "fire-fang," doing harm where it is little expected.

Now all this mischief is quite easily prevented. If the dung, as it is removed daily from the stable and cattle-houses, were spread evenly over the heap in layers, and well packed—tramped with cattle, perhaps, in covered courts—and moistened by having the liquid manure from the tanks pumped over it once a week, *there would be no fire-fanged dung upon the farm.* It is a simple cure, but quite effective. By careful and constant attention to this simple method, enormous loss which now takes place every year would be entirely saved. Cutting litter into short lengths helps greatly in avoiding "fire-fang" and in making first-class manure.

Dung from Different Stock.

Horse and Cow Dung Compared.—The dung from a cow-byre put in a covered pit, direct from the byre, will probably remain a long time, after the arrival of warm temperature, unsusceptible of fermentation; and perhaps it is from this property that cow-dung has received the character of being a *cold* manure; whereas horse-dung easily ferments, and goes rapidly through the stages of destructive fermentation, termed "fire-fanging," and is said to be a *hot* manure. Both dungs mixed form a valuable manure. The hot nature of horse-dung, and its rapidity of fermentation, are supposed partly to arise from its containing more nitrogenous matter than cow-dung; but, according to the analyses by Boussingault, it would seem that it is only as long as the dung is fresh that that supposition is well founded. The analyses are—

	Fresh dung.		Dry dung.	
	Cow.	Horse.	Cow.	Horse.
Water . . .	90.60	75.31	...	...
Nitrogen . .	0.22	0.54	2.3	2.2
Saline matter	1.13	4.02	12.0	16.3

"From these analyses," remarks Professor Johnston, "it appears that, though recent cow-dung contains more water than horse-dung, yet the dry matter of the former is

richer in nitrogen than that of the latter. Were this generally the case, it ought, one would suppose, after becoming a little drier, to ferment, or be as warm as horse-dung. However this may be, the two circumstances—that the nitrogen of the food is discharged chiefly in the urine, and that the cow voids a much larger quantity of urine than the horse—incline me to believe that cow-dung must *generally* contain less nitrogen than that of the horse, and that this is really the cause of its greater coldness. The correctness of this opinion can only be tested by a series of careful analyses. At the same time it is proper to add that the peculiar state of combination in which the nitrogen exists in two bodies, supposing the proportion in both to be the same, may modify very much the rapidity of the decomposition they respectively undergo in the same circumstances.

"Though fermenting with such apparent slowness, fresh cow-dung undergoes in forty days a loss of one-fifth of its solid matter (Gazzeri). Though this result was observed in Italy, yet there is sufficient loss in our climate also to make it worth the while of an economical farmer to get his cow-dung early in heaps, and to shelter it as much as possible from the sun and air. Even when fed on the same food, the dung of the horse should be richer than that of the cow, because of the large quantity of urine the latter animal is in the habit of voiding. In the short period of twenty-four hours, horse-dung heats, and begins to suffer by fermentation. If left in a heap for two or three weeks, scarcely seven-tenths of its original weight will remain. Hence the propriety of early removing it from the stable, and of mixing it as soon as possible with some other material by which the volatile substances given off (much ammonia) may be absorbed and arrested."

Pigs' Dung.—"Pigs' dung is still colder and less fermentable than that of the cow. . . . A specimen examined by Boussingault was found to contain per cent—

	Recent.	Dry.
Water . . .	81.00	...
Nitrogen . .	0.63	3.37

being richer in nitrogen even than horse-dung." Our experience determines pigs'

dung to be hot and excellent; and this was also the opinion of the ancients, as the Quintilli remarked, that "the dung of hogs, being of superior goodness, is improper for corn-fields on account of its abundant heat, for it instantly burns corn grounds."¹

Sheep's Dung.—"Sheep's dung is a rich dry manure, which ferments more readily than that of the cow, but less so than that of the horse. Boussingault found a specimen to consist of—

	Recent.	Dry.
Water . . .	63.0	...
Nitrogen . .	1.11	1.99

The food of the sheep is more finely masticated than that of the cow, and its dung contains a little less water, and is richer in nitrogen; hence, probably, its more rapid fermentation."²

Quantities of Dung from Stock.—The following quantities of dung have been obtained from horses and oxen from given quantities of food in a given time:—

A horse produces $\frac{3}{4}$ of the weight of food he consumes in manure.

A horse makes 12 tons of manure in a year, of superior quality to that of oxen.

An ox fed on turnips or mangel, with 24 lb. or 28 lb. of straw, gives 150 lb. of dung and urine a-day in winter.

An ox fed on turnips, corn, and hay, in seven months in winter produces 12 tons of manure, and in summer 7 tons more. With just enough straw to keep it clean, an ox will make 1 ton each month; all extra litter going to increase that quantity.

An ox fed in a box produces 11 cubic yards of manure in four months, or 33 cubic yards in a year.

An ox's dung is better than a cow's.

Conditions influencing Excreta.—The value of animal excrements as manure depends very much upon the age of the animals, their kind, their mode of employment, the kind and quantity of food they eat, and the nature of the water they drink. Thus: age has effect, for the excrements of a full-grown animal are much better than those of young

¹ Owen's *Geoponika*, i. 68.

² Johnston's *Lec. Agric. Chem.*, 2nd edition, 821, 822.

animals. The state of the animal has an effect, the manure from oxen being much better than that from cows, a great proportion of the substance of whose food goes to the production of milk; and in like manner, the manure of the wether is better than that of the ewe. The kind of food has an effect; for poor and scanty food cannot supply so rich manure as nourishing and abundant food.

System of Feeding and Value of Dung.—The system of feeding is in the main responsible for the original quality of the dung. The feeding of draught-horses varies but slightly, so that farm-horse dung is comparatively even in character. With cattle—by which the great bulk of farmyard manure is made—the case is very different. All sorts of dietary are given to them; from very poor and scanty—such as will barely sustain the existing “condition” of the animal—to very rich and abundant, far beyond the power of the animal to assimilate. Then in one case the supply of litter, generally cereal straw, which has little manurial value, may form a much larger proportion of the bulk of the dung than in another.

Obviously, therefore, there must be many degrees of quality in farmyard dung,—a fact which farmers should keep carefully in view in considering how many tons of dung, and what supplementary manure, should be given to this field or that. Moreover, as has just been seen, the original character of the dung may be greatly altered—improved or damaged—by the manner in which it is made, and treated generally. These considerations should never be lost sight of. One ton from a certain dung-heap may be worth two tons from another.

Manurial Value of Straw.—The straw of the cereal crops does not possess such high manurial value as is by many accorded to it. The constituents of fresh straw are for the most part insoluble, so that straw is of little use in the soil unless it is well rotted. Indeed, the principal value of straw in the making of manure is that it, in the first place, forms comfortable litter for the animals, and thereafter becomes a suitable vehicle for absorbing and holding in a manageable condition the solid and liquid ex-

creta. From this it is apparent that the excessive use of straw as litter is imprudent and wasteful; for, while the bulk of the dung may be thereby greatly increased, there may be little more fertilising value than if one-third less litter had been supplied.

Composition of Dung.—From the foregoing it is of course obvious that the chemical composition of farmyard dung is liable to great variation. The late Prof. Warington, in the most recent edition of his valuable book on the *Chemistry of the Farm* (1902), gives the following useful general statement: “Farmyard manure will contain from 65-80 per cent of water. The nitrogen will usually be about 0.45 per cent, but may rise to 0.65 per cent or higher if produced by highly fed animals, or with peat-moss litter. The ash constituents will be 2.5 to 3 per cent, exclusive of the sand and earth always present. Of these ash constituents 0.4 to 0.8 will be potash, and 0.2 to 0.4 phosphoric acid. One ton of farmyard manure will thus supply 10 to 15 lb. of nitrogen, 9 to 18 lb. of potash, and 4 to 9 lb. of phosphoric acid.”

To illustrate differences produced by feeding, we may give the following comparative analyses of two samples of dung made in close boxes, with and without cake, by Prof. Wood of Cambridge:—

	No Cake.	Cake Fed.
Water	77.15	75.90
*Dry matter	22.85	24.10
	<u>100.00</u>	<u>100.00</u>

*Including—

Nitrogen	.318	.574
Phosphoric acid	.075	.190

The same dung after being stored 6 months gave—

Water	76.80	74.70
*Dry matter	23.20	25.30
	<u>100.00</u>	<u>100.00</u>

*Including—

Nitrogen	.383	.576
Phosphoric acid	.105	.290
Potash	1.010	1.110

The no-cake dung had, however, lost about 28 per cent of its original weight

during storage, and the cake-fed dung about 35 per cent of its weight.

The following detailed analyses of samples of farmyard dung were made by the late Dr A. Voelcker.

Composition of *fresh* dung, composed of horse, cow, and pig dung, about fourteen days old :—

Water	66.17
*Soluble organic matter	2.48
Soluble inorganic matter	1.54
†Insoluble organic matter	25.76
Insoluble inorganic matter	4.05
	100.00

*Containing nitrogen	.149
Equal to ammonia	.181
†Containing nitrogen	.494
Equal to ammonia	.599
Total percentage of nitrogen	.643
Equal to ammonia	.780

Ammonia in a free state	.034
Do. in form of salts	.088

Composition of the whole ash :—

Soluble in water, 27.55 per cent.	Soluble silica	4.25
	Phosphate of lime	5.35
	Lime	1.10
	Magnesia	0.20
	Potash	10.26
	Soda	0.92
	Chloride of sodium	0.54
	Sulphuric acid	0.22
	Carbonic acid and loss	4.71

Insoluble in water, 72.45 per cent.	{	Soluble silica	17.34	
		Insoluble silicious matter	10.04	
		Phosphate of lime	...	
		Oxide of iron and alumina, with phosphates	8.47	
		containing phosphoric acid		(3.18)
		equal to bone earth		(6.88)
		Lime	20.21	
		Magnesia	2.56	
		Potash	1.78	
		Soda	0.38	
		Chloride of sodium		
		Sulphuric acid	1.27	
Carbonic acid and loss	10.40			

The composition of *rotten* dung, mixed horse, cow, and pig dung, six months old, dark brown, almost black in colour, well fermented and short, is as follows :—

Water	75.42
*Soluble organic matter	3.71
Soluble inorganic matter	1.47
†Insoluble organic matter	12.82
Insoluble inorganic matter	6.58
	100.00

*Containing nitrogen	.297
Equal to ammonia	.360
†Containing nitrogen	.309
Equal to ammonia	.375
Total amount of nitrogen	.606
Equal to ammonia	.735
Ammonia in a free state	.046
Do. in form of salts	.057

Composition of the whole ash :—

Soluble in water, 18.27 per cent.	Soluble silica	3.16
	Phosphate of lime	4.75
	Lime	1.44
	Magnesia	0.59
	Potash	5.58
	Soda	0.29
	Chloride of sodium	0.46
	Sulphuric acid	0.72
Insoluble in water, 81.73 per cent.	Carbonic acid and loss	1.28
	Soluble silica	17.69
	Insoluble silica	12.54
	Phosphate of lime	...
	Oxides of iron, alumina, with phosphates	11.76
	containing phosphoric acid	(3.40)
	equal to bone earth	(7.36)
	Lime	20.70
	Magnesia	1.17
	Potash	0.56
	Soda	0.47
	Chloride of sodium	...
Sulphuric acid	0.79	
Carbonic acid and loss	16.05	
		100.00

A Complete Manure.—Thus it is seen that, chemically, farmyard dung is a universal manure, because it contains *all* the constituents of our cultivated crops; and it is a perfect manure, because its constituents are in a state of combination favourable for the luxuriant growth of our crops.

Fresh and Rotten Dung.—On the whole, weight for weight, rotten dung is richer in soluble fertilising constituents than fresh, and contains more readily available nitrogen, and therefore produces a more immediate and powerful effect in vegetation. The preference which is evinced by farmers for rotten over fresh dung is thus sanctioned by chemistry.

Fixing Ammonia.—Ammonia is generated in large quantities during the putrefaction of the nitrogenised constituents of dung. This free ammonia is liable to be lost. Fortunately some natural provision is made for its con-

servation. The straw in course of putrefaction is, to a great extent, converted into humic and ulmic acids, which have a powerful affinity for ammonia, and, to a great extent, fix the ammonia as it is generated. These acids form, with potash, soda, and ammonia, a dark-coloured, very soluble compound. Hence the dark colour of the drainage of dung-heaps. Considerable losses of free nitrogen may also take place during the fermentation of dung.

Dr Anderson on Dung.—The chemical remarks of Anderson on the analyses of Voelcker are worthy of attention by the farmer: "On comparing and examining these analyses, it appears that the differences are by no means great, although on the whole they tend to show, weight for weight, well-rotted dung is superior to fresh, *provided it has been properly treated*. Not only is the quantity of valuable matters existing in the soluble state materially increased, whereby the dung is enabled to act with greater rapidity, but, owing to evaporation and escape of carbonic acid, produced by the decomposition of organic substances, the proportion of those constituents which are most important to the plant is increased. This is particularly to be noticed in regard to the nitrogen, which has distinctly increased in all cases in which the dung has been kept for some time; and the practical importance of this observation is very great, because it has been commonly supposed that, during the process of putrefaction, ammonia is liable to escape into the air. It would appear, however, that there is but little risk of loss in this way, so long as the dung-heap is left undisturbed; and it is only when it is turned that any appreciable quantity of ammonia volatilises. It is different, however, with the action of rain, which soon removes by solution a considerable quantity of nitrogen contained in farmyard manure; and the deterioration must necessarily be conspicuous in rotten dung, which sometimes contains nearly half of its nitrogen in a soluble condition. . . . Well-made and well-preserved farmyard manure will generally be found to differ comparatively little in value; and when bought at the ordinary price, the purchaser is pretty sure to get full

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value for his money, and the specialties of its management are of comparatively little moment to him. But the case is very different when the person who uses the manure has also to manufacture it. Though the manure made in the ordinary manner may, weight for weight, be as valuable as at first, the loss during the period of preservation is usually very large, and it becomes extremely important to determine the mode in which it may be reduced to the minimum. In the production of farmyard manure of the highest quality, the object to be held in view is to retain, as effectually as possible, all the valuable constituents of the dung and urine. In the management of the dung-heap there are three things to be kept in view: first, to obtain a manure containing the largest amount of nitrogen; secondly, to convert that nitrogen more or less completely into ammonia; and, thirdly, to retain it effectually."¹

Fertility in a Ton of Dung.—Even greater variations than these are to be met with in the analyses of farmyard dung. The manurial value of dung is governed by the amount it contains of nitrogen, potash, and phosphoric acid. The quantity of these in one ton may range as follows:—

	lb.
Nitrogen	8 to 16
Potash	8 to 18
Phosphoric acid	2½ to 9

A ton of first-class well-made farmyard dung, all kinds mixed, should contain the following, or thereby:—

	lb.
Nitrogen	12 to 14
Potash	11 to 15
Soluble salts of phosphoric acid (equal to soluble phosphate of super-phosphate)	8 to 9
Insoluble phosphates (as in bones)	10 to 13

Produce of Dung per head of Stock.

—The quantity of dung produced by a given number of stock will vary with the class of stock, the amount of food consumed, the quantity of litter supplied, and the amount of rain-water admitted amongst the dung. Each farm-horse will make about 12 tons of dung in a year—producing about three-fourths of its food in manure. In stalls or covered

¹ Anderson's *Agric. Chem.*, 176-179.

courts, full-grown feeding cattle will each produce from 10 to 12 tons of dung in the year, allowing, say, from 10 to 20 lb. of litter to each per day. In open yards the weight might be about 2 tons per head more. The solid excreta of an ox has been estimated at from 50 to 65 lb. daily, and liquid from 65 to 95 lb. daily. The above quantities of manure made by stock would thus be still greater if the whole of the urine were incorporated with the solid excreta and litter.

Fresh and Rotten Dung.—In reference to the effects produced by the rotting of farmyard dung, the late Dr A. Voelcker wrote:—

“Direct experiments have shown that 100 cwt. of fresh farmyard manure are reduced to 80 cwt. if allowed to lie till the straw is half rotten; 100 cwt. of fresh farmyard manure are reduced to 60 cwt. if allowed to ferment until it becomes ‘fat or cheesy’; 100 cwt. of fresh farmyard manure are reduced to 40-50 cwt. if completely decomposed.

“This loss not only affects the water and other less valuable constituents of farmyard manure, but also its most fertilising ingredient, nitrogen. Chemical analysis has shown that 100 cwt. of common farmyard manure contain about 40 lb. of nitrogen; and that during fermentation in the first period 5 lb. of nitrogen are dissipated in the form of the volatile ammonia; in the second, 10 lb.; in the third, 20 lb. Completely decomposed common manure has thus lost about *one-half* of its most valuable constituents.

“According to other experiments, the loss on the weight of fresh, common, mixed farmyard manure, at different periods, approximately, is as follows:—

“10 cwt. of dry food and straw yield—

	cwt.
Of recent dung . . .	23 to 25
At the end of six weeks . . .	21
After eight weeks . . .	20
When half rotten . . .	15 to 17
When fully rotten . . .	10 to 13.”

Town Stable Manure.—This is largely purchased by farmers living within easy carriage distance of large cities. The following are analyses¹ (by Dyer) of two

average samples of fresh “London dung” (mixed straw and peat dung):—

	No. 1.	No. 2.	Average.
Moisture . . .	76.09	61.98	69.04
Organic matter and loss on ignition . . .	19.30	26.37	22.82
* Phosphoric acid . . .	0.33	0.45	0.39
Lime . . .	.55	1.28	0.92
Potash . . .	.45	.58	.51
Magnesia, soda, and other undetermined constituents . . .	.69	2.70	1.70
Silicious matter—(mainly sand) . . .	2.59	6.64	4.62
	<u>100.00</u>	<u>100.00</u>	<u>100.00</u>

* = Phosphate of lime . . .	.72	.98	.85
Total nitrogen—			
Soluble . . .	.08	.08	.08
Insoluble . . .	.46	.62	.54
Equal to ammonia—			
Soluble . . .	.10	.10	.10
Insoluble . . .	.56	.75	.66

The following are analyses (also by Dyer)¹ of stable manure made respectively with peat-moss litter and with straw litter:—

	Stable manure made with	
	Peat moss litter.	Straw litter.
Moisture . . .	77.84	70.03
Organic matter, &c. (loss on ignition) . . .	18.02	24.28
* Phosphoric acid . . .	.37	.48
Lime . . .	.33	.70
Potash . . .	1.02	.59
Magnesia, soda, and other undetermined constituents . . .	1.08	1.30
Silicious matter . . .	1.34	2.62
	<u>100.00</u>	<u>100.00</u>

* = Phosphate of lime . . .	.80	1.04
Total nitrogen—		
Organic . . .	.37	.52
Ammoniacal and nitric . . .	.51	.10
Equal to ammonia . . .	1.07	.75

It will be seen that the peat litter shows a larger absorptive power for ammonia than straw does.

Dyer also gives analysis of London stable manure after being stored in large heaps in the open field for about six months—*i.e.*, from summer till February. From the ratios of phosphates to organic matter, and to soluble and insoluble nitrogen in these, it would appear that during storage something like 40 per cent of organic matter disappeared through fermentation and drainage, together with from one-sixth to one-fifth of the original total nitrogen. The loss of nitrogen, however, fell on the most valuable part—*viz.*, the soluble nitrogen,

¹ *Journal of Agricultural Science*, vol. i., part 1, pp. 108-113, 1905.

of which 25 to 40 per cent was lost in fermentation and drainage.

A Complete Manure.—Farmyard manure contains all the elements necessary for plant-growth, and is therefore a *complete manure*. If applied in sufficient quantity, it will, without any extraneous aid, maintain fertility even under an intense system of cropping.

Mechanical Uses of Dung.—As a manure, dung is valuable, not only for its chemical but also for its mechanical properties. Referring to this point, Sir John Bennet Lawes says that by reason of its bulk and the quantity of organic matter it contains, it serves to render the soil more open and porous, and so enable it not only to retain more water in a favourable condition, but also to absorb and retain more of the valuable constituents of the manure, and so arrest the passage of them in solution into the drains. Further, by the gradual decomposition of the organic matter of the dung, the pores of the soil become filled with carbonic acid, which probably serves to retard the oxidation of the ammonia into the more soluble form of nitric acid, in which it would be more liable to be washed out and lost by drainage. From these facts, Sir John considers it will be readily understood how it is that dung is more lasting in its effects than the more active artificial manures.¹

It is well known that, by repeated applications of farmyard dung, stiff clays have been rendered more friable. And its mechanical influence on such soils is more effective when the dung is applied in a rank state,—that is, before the straw it contains—or rather, the straw which contains the manure—has become thoroughly rotten.

Dung Heating Soil.—Then it is equally certain, though not so generally recognised, that a heavy dressing of rank dung benefits the soil by raising its temperature. "The temperature of the soil is affected by other causes than the sun's rays. Decaying vegetable matter is a source of heat, as evidenced by the high temperature arising from the fermentation of dung: Farmyard manure thus supplies heat to the soil from two different sources, while it helps to

retain much valuable manurial ingredients, which, in a more purely mineral soil, would be washed away."²

Lasting Influence of Dung.—The great lasting influence or "staying power" of farmyard manure is an important factor in practical agriculture. For the full understanding of the extent, advantages, and risks of this enduring power and slow-acting characteristic of farmyard dung, it is necessary to refer the reader to the results of the Rothamsted investigations, as described in the next volume, under the heading of "Rothamsted Experiments." By the Rothamsted experiments valuable information was supplied as to the accumulation of fertility in soil heavily dressed with dung; as to the lower immediate efficiency of the nitrogen in dung, as compared with a corresponding amount of nitrogen supplied in ammonia-salts or nitrate of soda; as to the loss of the nitrogen of dung in nitrates formed during autumn and winter, and washed away in drainage-water; and as to the loss of surplus nitrogen—that is, of available nitrogen not immediately assimilated by a growing crop—by evaporation in the form of nitrogen gas.

Similar results are shown in the Rothamsted barley experiments. For twenty years up to 1871, 14 tons of dung were applied every year to one plot for barley, and the average produce was 48¼ bushels. No further manure of any kind was applied to this plot, upon which barley was continued, with the result that the average yield for the next twelve years fell off by about one-third. It was estimated that of the 4000 lb. of nitrogen per acre supplied to the soil in the 14 tons of dung for twenty years, only about 14 or 15 per cent had been recovered in the increase of crop. From this it was calculated that if all the remaining 3400 lb. of nitrogen had been stored up in the soil, in a form as available as that which had already been used in the crop, this plot should have been able for 150 years to produce an average of 48 bushels of barley per acre per annum. Yet with the stopping of the annual dressing of dung, the crop showed a very marked decline.

¹ *Jour. Roy. Agric. Soc. Eng.*, ii. 8, 1875.

² *Mark Lane Express*, 1889.

How is this decline to be accounted for? There had, no doubt, been some loss of nitrogen in drainage, and some may have been volatilised. But, upon analysis, the soil was found to contain a great accumulation of nitrogen, as well as other constituents. This great accumulation of nitrogen and other constituents of the dung, if it had remained in the soil in a *sufficiently available* form, would have supplied the crop with all the food it could absorb for many years. Why, then, does this abundant residue give such a poor account of itself? In reference to this important question, Sir Henry Gilbert remarks "that it is only the comparatively small proportion of the nitrogen of farmyard manure which is due to the liquid dejections of the animals that is in a readily and rapidly available condition; whilst that due to more or less digested matter passing in the *fæces* is more slowly available, and that in the litter remains a very long time inactive."

The potato experiments at Rothamsted afforded equally striking evidence of the slow recovery of the nitrogen supplied in dung. Fourteen tons of farmyard manure, applied every year for six years, yielded in potatoes only 6.4 per cent of its nitrogen; while in the next six years, the same crop every year, without any further dressing of manure, recovered from the residue only 5.2 per cent more—that is, only 11.6 per cent in the course of the twelve years. In other words, at the end of the twelve years there was still about 88 per cent of nitrogen supplied in the dung unrecovered by the crop.

An Old Custom Questioned.—All these are considerations which—although subject to modifications under ordinary farm practice—should have studious attention from farmers. They unquestionably suggest that in the past farmers have placed rather too much faith in farmyard manure,—that the old custom of manuring only once in a rotation—of applying with the root-crop a heavy dressing of dung, in the belief that what of the manure the roots do not appropriate will remain in the soil and be available for the use of the succeeding crops—may, in certain circumstances, be found to be seriously mistaken.

Loss of Residual Manure.—The un-used portions of the manure unfortu-

nately do not, in their entirety or nearly so, remain in the soil available for future crops. Much of this residue—of the most valuable portion of it too—is now found, under certain circumstances, to escape through channels which were formerly unsuspected as means of loss. The discovery of the great loss of excess or residual nitrogen by the washing away of nitrates in drainage-water, and by evaporation as nitrogen gas, throws new light upon the theory and practice of manuring, which farmers cannot afford to disregard.

Soil an Unreliable Custodian of Manure.—In times past we have placed too much faith in the soil as the custodian of costly manure. While nourishing a growing crop, the soil is commendably faithful to its trust, and does not then readily part with its available plant-food, except to the crop itself. But the moment the crop is removed, the soil loses retentive power, and if the conditions favourable to the washing away or volatilising of nitrogen are present, loss of residual nitrogen is liable to set in. Moreover, results obtained at Rothamsted seem to suggest the question whether some portion of the nitrogen which accumulates in the soil may not, in certain circumstances, undergo some sort of reversion by which it is rendered more slowly instead of more readily available to the crops. In some soils of an open gravelly texture, sometimes appropriately called "hungry" soils, the rapidity with which heavy dressings of dung disappear by oxidation and washing away is astounding.

Superiority of Dung Questioned.—Now nitrogen is the most costly of all the elements of manure. It is therefore obviously desirable that it should not only be drawn from the cheapest sources, but should also be supplied to the soil so as to guard as far as possible against any portions of it being lost in the manner just described. At first thought, one might say that the best plan would thus be to apply nitrogen in a readily available form, just when it is required by the crop, and only in such quantity as may supply the wants of that particular crop. This is, no doubt, sound enough theoretically, and may often be carried into practice with the best possible results.

But such a course will not, as a rule, be practicable. It would practically exclude the use of farmyard manure; and while it would be unwise to overlook or disregard the important results obtained under certain conditions at Rothamsted, it would be a still more serious error now to hastily jump to the other extreme, and unreasonably depreciate or discredit the great value of the fertilising materials in the solid and liquid excreta of farm animals.

Practical Conclusions.—The practical points to be kept in view are, that from the investigations as to the behaviour of nitrogen in the soil, it is seen that the enduring character of farmyard manure in average soils is not an unmixed advantage to the rent-paying farmer; that the excess of nitrogen accumulated in the soil by heavy dressings of farmyard manure is, in certain circumstances, liable to serious losses by drainage and evaporation, and cannot, therefore, in all cases be to the *full extent* depended upon for the nourishment of future crops; that, therefore, the practice of so entirely or mainly trusting to heavy dressings of dung at long intervals for the production of profitable crops is neither reliable nor economical; and that the loss of nitrates from land which is rich in residual nitrogen may be reduced to a minimum by having the soil covered with vegetation throughout the entire year, or in cold northern districts by having it bare only in the winter months when the temperature is usually too low for the formation of nitrates to proceed in the soil.

Vegetation Preventing the Loss of Nitrates.—For the last-named object many farmers, especially in England, sow some forage crop, perhaps rye, soon after the removal of a cereal crop. This not only engages the attention of unused nitrogen, thus preventing the washing away of nitrates, but affords a useful feed to sheep in early spring, and likewise further enriches the soil when ploughed down. If a leguminous crop, such as vetches or trifolium, be thus grown, it actually enriches the soil by the addition of nitrogen drawn from the atmosphere.

Cold Weather and Loss of Nitrogen.—The above safeguard, to be sure, cannot be provided in the cold regions of

the north, but then there is, fortunately, much less necessity for it there. It is in the form of nitrates in which nitrogen is washed away in drains. Nitrogen is transformed into nitrates by the operation of myriads of living atoms, commonly called *bacteria*. In very cold weather, with the temperature at or near to freezing-point, these wonderful little atoms of life seem, with commendable beneficence, to relapse into idleness; so that at this cold season of the year the northern farmers may with tolerable, if not complete, immunity from loss of nitrogen, till their land and leave it exposed to the action of frost, as has been their wont from time immemorial.

Making Dung or Selling Crops.—We are not to discuss fully the question as to whether farmers should endeavour to make as much dung as possible, or should sell produce and purchase artificial manures. Local circumstances vary so much that the conditions which determine the best system in one case may not apply equally to another. Much will depend on the locality and character of the holding, and the tastes of the tenant—whether favourable to the breeding and feeding of stock, or the growing and selling of crops; also upon the fluctuations of market prices—especially as to the relative prices of beef, feeding-stuffs, and litter, on the one hand, and of artificial manures on the other.

Farmers now less Dependent on Dung.—With the abundance of excellent artificial manure in the market, and with the great advance that has been made in the investigation and elucidation of the principles which govern economical and successful manuring, farmers are now much less dependent upon farmyard manure than in former times. They have no need any longer to consume their crops on the farm for the sake of providing manure with which to restore fertility to the soil. This may now be accomplished cheaply and efficiently by the use of other manurial substances, of which exhaustless supplies are at hand. It is unquestionable, therefore, that dung, as a source of plant-food, has been depreciated in its relative intrinsic worth, and in its importance as a factor in agriculture; and that it should not

count for so much on the credit side of the feeding account as it has often done in times gone by.

Dung not likely to Diminish in Production.—But farmyard manure is a necessary accompaniment of the rearing and feeding of stock, and there is little likelihood that, with the growing importance of the live-stock industry, there will be any falling off in the production of farmyard manure. In all probability it will be of a more concentrated character than in former times. Straw is now being turned to better purpose as food for stock, or in other ways than as litter for cattle. The animals may therefore be littered with smaller quantities of straw, or with other substances less bulky, such as peat-moss litter. But while the dung may thus be more concentrated, and less bulky per head of stock than it would be with freer use of straw as litter, it is not likely that the amount of fertilisers annually available in the form of farmyard manure for application to the soil will be less in the future than it has been in the past.

A Word for Dung.—Although farmyard manure is not likely to lose its hold upon the affections of British farmers, it nevertheless seems desirable to remind the reader that in considering the practical lessons to be drawn from the Rothamsted experiments with dung and other manures, it should be kept in view that these experiments were not framed as a guide to farmers in pursuing the ordinary routine of farm practice. The scientific conclusions arrived at are undeniably of great value to farmers, but it would be imprudent to attach to them a significance which they were not intended to and do not possess. If the course of cropping and systems of tillage pursued at Rothamsted had been similar to those observed in the rotations followed throughout the country, the dung would, in all probability, have given a much better account of itself. In particular, it is probable that the accumulation of inert nitrogen would have been roused to greater activity and usefulness, so that under a rotation of crops, with the thorough tillage necessary for roots, the influence of the residue of the dung would have been more marked than it has been upon the continuous growth of the same crops on the same respective plots.

Professor Wrightson on Dung.—Professor Wrightson was a strong advocate of the superiority of farmyard dung over artificial manures. As to the reasons why he thought farmyard dung should hold a strong position in the estimation of the British farmer, he said :—

“The first reason, no doubt, is what has been already advanced—the general composition of dung. A great many science students stop here. When they are asked why farmyard manure is a more potent and more valuable manure than many artificial fertilisers, they say it is because of its general composition. But there are a good many other reasons beside, one of which is, no doubt, its effect upon the mechanical condition of the soil—a subject which we have already had before us, and which it is therefore not necessary to further enlarge upon. Then, in the third place, there is the reaction of the carbonic acid gas which is evolved from farmyard dung, upon the mineral matter in the soil. I do not doubt in the least that it digests the soil.

“I do not doubt that Jethro Tull was perfectly right when he said farmyard manure prepared plant-food. No doubt it does ; it is the source of carbonic acid gas, and we know that that gas in watery solution reacts on the mineral matter in the soil with great effect.

“Now take another reason. Farmyard dung is rich in nitrogen ; that alone places it on a superior basis to most artificial manures. It is rich in nitrogen in a state of organic combination, from which it is liberated slowly by the process of decay, that liberation of nitrogen being known as nitrification. Performed under favourable temperatures, with access of air, and no doubt also assisted by the agency of certain bacteria which work in the soil and produce the peculiar fermentation necessary, this nitrification of farmyard manure in the soil is arrested at freezing-point. It proceeds very slowly at low temperatures, and with accelerated speed at higher temperatures. Especially does it take place freely during the summer months, when vegetation is most luxuriant.

“Hence farmyard manure subjected to gradual decay yields up its materials, especially nitrogen oxidised into nitrates, at that period of the year when they are

wanted. It is worth notice that the same forces which liberate nitrogen must also liberate the mineral and other constituents of farmyard dung, gradually and as required."¹

LIQUID MANURE.

Its Composition and Character.

The liquid manure of the farm consists of impure and diluted urine, comprising the oozings from manure-heaps and farm-yards, the wash from byres, stables, and

piggeries, and the whole surface-drainings of a farm-steading, assumed to meet and mingle in one common stream or reservoir. In this sense pure urine does not form ordinary liquid manure; but as it constitutes the source and the basis of the chief ingredients that impart to liquid manure its high fertilising properties, it is proper, in the first place, in order clearly to understand the character of the latter, to examine in some detail the composition of the urine of the different animals of the farm.

The following analyses by Stoeckhardt shows the

Composition of Urine of different Animals.

	Sheep. (Fed with hay.)	Swine. (Meagre diet, chiefly potatoes.)	Horses. (Hay and oats.)	Cows. (Hay and potatoes.)
	Per cent.	Per cent.	Per cent.	Per cent.
Water	86.5	97.5	89.0	92.0
Solid matter	13.5	2.5	11.0	8.0
Ashes	3.6	1.0	3.0	2.0
Organic matter . . .	9.9	1.5	8.0	6.0
Nitrogen	1.4	0.3	1.2	0.8
Phosphoric acid . . .	0.05	0.12	...	...
Alkalies	2.0	0.2	1.4	1.4
Lime and magnesia . .	0.6	0.05	0.15	0.15
Sulphuric acid	0.4	0.05	0.15	0.15
Salt	0.25	0.5	0.1	0.1
Silica	trace	trace	0.025	0.01

Complex Character of Excreta.—

The solid and fluid excrements of animals form a very complicated mixture, as may be seen from the following enumeration by Sprengel; but this renders them the more valuable a manure for vegetables:—

1. Vegetable or woody fibre.
2. Wax and resin.
3. Chlorophyll, or the green substance of leaves, partly decomposed.
4. Deposited humus.
5. A fatty and oily substance.
6. Mucus.
7. A peculiar brown colouring matter, in the solid excrement of oxen.
8. Vegetable albumen (hardened).
9. Animal gelatine.
10. Animal fibre.
11. Salivary matter.
12. Osmazone.
13. Hippuric acid.

} Originating in the urinary passages.

14. Uric acid.
15. Lactic acid.
16. Benzoic acid.
17. Urea.
18. Bilious matter.
19. Bilious resin.
20. Picromel.
21. Oxides of iron and manganese, derived from vegetables.
22. Earths—silica, lime, alumina, magnesia.
23. Salts, consisting of mineral acids and bases, derived from plants and water.
24. Common salt.
25. Carburetted hydrogen.
26. Phosphoretted hydrogen.
27. Sulphuretted hydrogen.
28. Ammonia.
29. Hydrogen.

} Products of the fermentation and putrefaction of the food in the bodies of animals.

Numerous as these substances are, it was Sprengel's opinion that many more might be discovered by carefully conducted chemical analyses.

¹ *Principles of Agric. Prac.*, 152.

Conditions influencing Urine.—Age, method of feeding, and condition of the animal have an influence on the composition of the urine. The water drunk has also an effect: an ox that drinks 80 lb. of water a-day will pass more urine than a cow which drinks the same quantity, because a large proportion of the water she drinks goes to the formation of milk. Boussingault found that a cow which drank 132 lb. of water a-day passed 18 lb. of urine, and gave 19 lb. of milk; an ox that drank the same quantity gave 40 lb. of urine; a horse that drinks 35 lb. a-day passes 3 lb. of

urine—no more than a man, which fact seems remarkable; but when we consider the much greater extent of surface over the body of a horse compared to that of a man, the insensible perspiration of the horse, it is seen, must carry off a large proportion of the liquid food; whereas a man drinks daily only one-tenth more than the urine he passes.

Fresh and Stale Urine.—A comparison of the composition of *cows' urine* fresh, and after it has been kept a month, will show the change that takes place in it by exposure to the air:—

		Cows' urine.	
		Fresh.	A month old.
Water in 100,000 parts by weight		92,624	95,442
Urea, along with some resinous colouring matter		4,000	1,000
Albumen		10	...
Mucus		190	40
Benzoic acid (hippuric acid)	} combined with potash, soda, and ammonia, forming salts	90	250
Lactic acid		516	500
Carbonic acid		256	165
Acetic acid		...	1
Ammonia		205	487
Potash		664	664
Soda		554	554
Sulphuric acid	} combined with soda, lime, and magnesia, forming salts	405	338
Phosphoric acid		70	26
Chlorine		272	272
Lime		65	2
Magnesia		36	22
Alumina		2	0
Oxide of iron		4	1
Oxide of manganese		1	...
Silica		36	5
Sulphuretted hydrogen		...	1
Sediment, consisting of phosphate and carbonate of lime, and magnesia, alumina, silica, and oxide of iron and of manganese		...	180
		100,000	100,000

occurring partly in an uncombined state.

Decomposition of Urine.—In winter, urine scarcely contains half the quantity of urea stated in the first column, and is then, of course, of less value; and when it has been putrefying for a month, it contains more than as much again of ammonia as urine in a fresh state. The ammonia is derived from the decomposition of the urea, and the other organic bodies containing nitrogen. The caustic ammonia remains partly dissolved in the water, and is the substance through which urine not properly putrefied is so apt to injure plants.

If exposed long to the atmosphere, the caustic ammonia absorbs from it carbonic acid, becomes mild, and the urine may then be employed without danger as a

manure for vegetation. But on urine being thus exposed to the air, part of it will escape in the form of gas, unless some substance is added to the putrefying urine to neutralise the ammonia—to fix it, as it is usually termed.

Fixing Ammonia.—The fixing of the ammonia is often done by adding water to it, which, of equal bulk to the urine, enables the diluted mass to retain four times as much ammonia—that is, in every 100,000 lb. of diluted urine, 1135 lb. more of ammonia is retained.

Another simple substance for fixing the ammonia is black vegetable mould, which supplies humic acid, and every 90 lb. of it saturates 10 lb. of ammonia;

but as the best earth contains only 45 per cent of humic acid, 200 lb. of earth will be required to fix every 10 lb. of ammonia.

Gypsum is now extensively used for this purpose. It may also be effected by adding sulphuric acid, at the rate of a gill of the acid to every 18 or 20 gallons of the liquid manure. This is preferable to water, as it lessens carting.

Changes through Decomposition.—It is rather important to trace the change in liquid manure occasioned by keeping. Fresh urine of cattle has a yellow colour, occasioned by a small quantity of resinous colouring matter; but on standing exposed to the air, the yellow assumes a brown, and at length a black colour, attributable to the formation of humic acid. In winter, urine does not possess a trace of ammonia, whereas it does in summer, thereby indicating the decomposition of urea by heat in the body before the emission of the urine.

The above table shows that exposure of urine for a month to the air has the same effect of decomposing the urea as heat has in the body; and four weeks are not sufficient time to decompose all the urea, as still 0.6 remains. When exposed for three months and longer, urine loses its carbonate of ammonia, which is evaporable as well as the crude ammonia itself.

In short, a six months' urine contains not a trace of its original urea, mucus, and albumen, and new acid combinations take place, such as the lactate, humate, sulphate, acetate of ammonia.

Urine is supposed to be in a ripe state after it has putrefied in summer for five or six weeks, and in winter for eight or nine, though no absolute rule can be laid down on this point, so much depending on the evaporation of the air. The chemical rule for knowing the ripeness of urine is when it contains neither urea nor caustic ammonia, and this can be ascertained only by chemical investigation.

After exposure to the air a year and half, urine contains no organic remains, and only salts and mineral bodies dissolved in water.

Specific Gravity of Urine.—The specific gravity of the urine of the horse, according to Fourcroy and Vanquelin,

varied from 1.03 to 1.05; according to Prout, 1.029; and to Boussingault, 1.064.¹

Composition of its Saline and Mineral Ingredients.—The saline and mineral ingredients of the urine of the horse, ox, sheep, and pig, consist of the following substances:—

	Horse.	Ox.	Sheep.	Pig.
Carbonate of lime	21.75	1.07	0.82	..
" magnesia	11.26	6.93	0.46	..
" potash	33.12	77.28	..	12.1
" soda	15.16	..	45.25	..
Chloride of sodium	6.27	0.30	32.01	53.1
" potassium	..	..	12.00	little
Sulphate of soda	11.03	..	7.72	7.0
" potash	..	13.30	2.98	..
Phosphate of soda	..	..	..	19.0
" lime	..	..	..	..
" magnesia	..	..	0.70	..
Silica	0.52	0.35	1.06	8.8
Oxide of iron and loss	0.79	0.77	..	..

The conclusion Professor Johnston comes to, in reference to the contents of this last table, is, that "the fermenting urine of our domesticated animals cannot afford phosphoric acid, which must be conveyed to the soil by the solid excrements."²

Valuable Character of Liquid Manure.—The analyses given show clearly whence urine derives its great manurial value. If we take the average composition of the urine of the four kinds of animals (table, p. 475), we find that thirty-five parts of the total solids in the urine contain 3.7 parts of nitrogen, or rather more than 10 per cent of the most costly substance that is purchased by farmers for manurial purposes. Three cwt. of the solids of urine contain approximately as much nitrogen as two cwt. of commercial nitrate of soda, or one and a half cwt. of sulphate of ammonia.

The mineral ingredients in urine must not be overlooked. In thirty-five parts of total solids, there are five parts alkalis, about one part each of salt, lime, and magnesia, and some phosphoric acid. Probably all these ingredients have some manurial value, and this is enhanced materially by the very fine state of division in which they exist.

Variation in its Composition.—Ordinary liquid manure, however, cannot be regarded as having a composition or value precisely identical with that of any of the kinds of urine mentioned. It has indeed in the main a similar character,

¹ Thomson's *Ani. Chem.*, 493.

² Johnston's *Lect. Agric. Chem.*, 2nd ed., 811.

and its high fertilising qualities are due to the same causes. But it is a less concentrated manure, and part of the substances in it which assist in raising its analytical standard of apparent merit are present in combinations less readily available for the use of plants, less immediate in their effects, and therefore in some degree of less intrinsic worth. It is necessarily liable to considerable variation of quality, according to the circumstances attending its production and management. The urine itself, as the analyses quoted have made manifest, alters in character with the species of animal producing it, and in some measure it also varies with the nature of the food with which the animal has been supplied.

But the liquid manure varies still more, according to the proportions in which each species of animal has contributed to it, and according to the nature and amount of the extraneous substances with which it has become commingled. As a rule, it consists most largely of the urine of cows or other cattle, with a less quantity from horses and pigs, mixed with drainings from the yards and middens or manure-heaps, and with some parts of earth and solid excrements.

Drainings from Yards and Dung-heaps.—Where the yards are entirely uncovered and exposed to the whole rainfall, the drainings from yards and manure-heaps form by far the bulkier portion of the liquid manure. The composition of this part of the mixture differs greatly from that of the original urine, not only because it is more or less diluted

with rain-water, but also because of the chemical changes that have occurred during the time occupied in its passage through the bulky mass of solid litter and manure, and because it contains some of the products of the decompositions that have taken place, as well in the solid as in the liquid excrements.

It is obvious, therefore, that in most cases ordinary liquid manure must differ very greatly from pure urine, and that the analyses we have examined of the latter can be serviceable only in that they enable us to see clearly what are the ingredients contained in liquid manure that are of use as fertilising agents, though they must by no means be accepted as showing precisely the forms and combinations in which these ingredients ultimately exist, nor as indicating their relative proportions to its whole volume.

Johnston on Liquid Manure.—“The drainage of dung-heaps,” says Professor Johnston—“the usual liquid manure of our farmyards—differs in composition according to circumstances. When the urine of cattle is mixed with it in considerable quantity, it is found to contain a portion of the constituents, not only of the solid and liquid excretions of the stock, but also of the straw and other vegetable matter which have fermented along with it. It varies in strength, however, very much with the quantity of rain or other water with which it is mixed, or which falls upon the dung-heaps from which it flows.” The composition of two specimens of such liquid is as follows:—

	Cow-dung washed by rain.	Drainings of Farmyard manure watered with cows' urine.
An imperial gallon contained—	Grains.	Grains.
Ammonia	9.60	21.30
Solid organic matter	200.80	77.60
Solid inorganic matter or ash	268.80	518.40
	479.20	617.30
Inorganic matter in a gallon consisted of—		
Alkaline salts	207.80	420.40
Phosphate of lime and magnesia, coloured with a little phosphate of iron	25.10	44.50
Carbonate of lime	18.20	31.10
Carbonate of magnesia and loss	4.30	3.40
Silica and a little albumen	13.40	19.00
	268.80	518.40

From these facts Professor Johnston concludes "that the liquid which flows from a dung-heap *watered with urine* is greatly richer in ammonia and in saline matter than that which flows from the solid excrements newly washed by the rain; that the liquid in both cases contains a considerable proportion of phosphate of lime. This does not exist in cows' urine alone. In both cases it has been washed out of the solid dung; and both contain also an appreciable quantity of silica not existing in urine. This is derived from the straw of the fermenting farmyard dung, or from the grass which has passed through the digestive organs of the cow. As fermenting manure can yield in a soluble state every mineral ingredient which a plant requires, the liquid that runs from the farmyard ought to be no less carefully preserved than the pure urine of our cattle."¹

Average Composition of Liquid Manure.—It would be impossible to state with absolute accuracy the percentage of useful substances, or even of total solids present in liquid manure, because the conditions hardly permit the selection of an average sample. It will not, however, be far wrong to accept Wolff's analysis as being fairly representative. He gives the average percentage composition as follows:—

Water	98.20
Organic matter	0.70
Ash ingredients	1.10
Nitrogen	0.15
Potash	0.49
Phosphoric acid	0.01
Lime	0.03
Magnesia	0.04

Liquid Manure Acts quickly.—The value of nitrogen in manures depends not only on its quantity, but also on the particular combination in which it occurs. An insoluble or slowly soluble form will give a less immediate return, and is consequently of less value, than one in which the nitrogen acts more rapidly on plants. In this respect urine takes a high position among manures. Its nitrogen, as uric acid, hippuric acid, &c., is entirely contained in solution. It is capable of being more readily and more widely distributed through the soil

than it is even in ammonia compounds, and it is at once available for the use of plants. Hence, urine is universally recognised in practice to be a "forcing" or quickly acting manure. It produces its full effects on the first crop to which it is applied, and its nitrogen is thus fully equal in value to that of the most expensive nitrogenous manures that are offered in the market.

The fact that the valuable ingredients of liquid manure are contained in solution in a large volume of water adds distinctly to the certainty and uniformity of their action, on such soils at least as are suitable for the reception of large quantities of liquid applications. Indeed the most striking characteristic of liquid manure, and that to which it owes its special differences from all other forms of manure, is the enormous bulk of water in which its valuable constituents are contained. It is necessary at this point to consider more particularly the effects produced by this special feature. They are of a twofold and contradictory character.

Advantages of the Liquid Form.—Except when employed in a fresh or undiluted form, burning effects seldom follow the application of liquid manure. It causes, besides, the most perfect distribution of the manure; for the water, in its slow circulation through the whole body of the soil and subsoil, conveys its valuable materials into every pore into which the tender rootlets of plants can penetrate. The important constituents of the manure, instead of being left in unequal lumps spread irregularly on the surface, or scattered in drills, from which they only become, slowly and with difficulty, diffused through the soil,—as may be the case with dry manures in dry seasons,—are deposited in the most minute state of subdivision through all parts of the soil.

Disadvantages of Excess of Water.—But the large quantity of mere water in liquid manure must also be considered in another aspect, that has a very important bearing on the whole problem of economical liquid manuring.

Dry artificial manures have this notable practical advantage, that they can be conveyed great distances, and can be applied to crops at an expenditure which

¹ Johnston's *Lect. Agric. Chem.*, 2nd ed., 812.

is relatively low in proportion to the amount of really valuable ingredients supplied.

But it is quite otherwise with liquid manure. The enormous bulk of water adds so much to the cost of handling as entirely to control the whole system and mode of using it. If we accept Wolff's average analysis, already given, we find that for two tons of solid substances added to our soils in liquid manure, we have to deal in no case with less probably than about 100 tons of water, and in many cases much more.

But before proceeding to consider the profitable utilisation of liquid manure, something may be said as to how it is to be conserved at farm-steadings.

Neglect of Liquid Manure.—The general body of farmers are not nearly so careful as they ought to be in the preservation of liquid manure.

The loss through leakage from dung-heaps in the field is not, as a rule, very serious—that is, if the dung-heaps have been properly formed, with a covering of earth, or some other material, to prevent rain-water getting into the dung to carry away its own rich juice. But at the steadings, the losses which arise from want of attention to liquid manure are often enormous—such as would greatly surprise the negligent farmers themselves if only they had the actual amounts of the losses “figured out” to them.

Often have we seen cattle-dung lying in heaps for weeks and weeks—perhaps even for months—as thrown from the cattle-byre, in such form as to press out its liquid contents rather than conserve them: a rich brown liquid oozing out freely at all sides, and passing away into utter uselessness.

Rainfall and Loss of Liquid Manure.—The heaviest losses in liquid manure occur where the rain-water from the roofs of the adjoining buildings and the open heavens is allowed to rush on to the dung-heap in the yard, and pass through it and go where it may without let or hindrance. It may sink into a porous soil, or find its way into a passing stream, carrying with it a great deal of the very richest of the ingredients of the manure.

Preventing Loss in Liquid Man-

ure.—Now it will readily occur to one that useful measures may be taken in two ways to prevent these losses. In the first place, by efficient water-spouts and roofed courts or dung-pits the rain-water may be prevented from reaching the dung. In the second place, arrangements may be made whereby any liquid escaping from the dung may be directed into some safe receptacle for preservation until it can be advantageously utilised. Already at various points, in treating of covered courts and of farmyard dung, we have referred to the various ways of covering cattle-courts and dung-pits, and to the advantages arising therefrom.

Liquid-manure Tanks.—Here we need, therefore, consider only the second of these measures whereby the loss of liquid manure may be averted—that is, the means whereby it may be preserved for useful application. There are various methods by which this may be done—the liquid-manure tank being the most general. Liquid-manure tanks of many sizes and designs are in use. The formation of drains and tanks for liquid manure, as they exist on many farms, is described in this volume at pages 159 and 160. In the cases there referred to it was not intended that any of the liquid should be returned to the dung, so that the tanks were not placed close to the dung-pit. Modern experience, however, inclines more and more towards placing the tanks so that when desirable the liquid (as will be presently explained) may be pumped out of them on to the manure, or into a liquid-manure cart when it is to be carried away. It is also desirable, on the score of expense, to have the tank near the cattle-court, and thus avoid unnecessary outlay on drains to conduct the liquid manure.

There are several circumstances to be taken into consideration before proceeding to construct a tank for liquid manure. When a tank is made deep, such as a well, the building of the lower part will require to be particularly strong, and, of course, will be so much the more expensive in construction. A tank should therefore be shallow, not deeper than 4 or 5 feet below the sole of the drains which bring the liquid manure. It is very desirable to have the tank covered,

for the sake of protection against accidents. The most durable covering is an arch; and to keep the cost of that within bounds, the tank should be narrow, not exceeding 6 feet. The desired capacity of a tank will thus be attainable by extending its length.

A tank should neither let in nor let out liquid. To prevent its letting in water, a drain should be formed where there is the least appearance of it in ooze or a spring; and to prevent the liquid getting out, a puddling of clay should be used, where the subsoil does not consist of tenacious boulder-clay. The clay for puddling should be well pugged, or beaten into the consistency of putty. A fall of from 6 inches to a foot is required along the floor, according to its length; and a roomy manhole should be made in the arch of the roof, at each end of the tank, and at the deepest end a third opening for the pump.

Liquid-manure Pump.—The pump used in tanks is generally the chain one, in which an endless chain passes from the bottom of the tank to the height to which it is desired to raise the urine, where it passes over a pulley, constructed so as to firmly hold the chain. On the chain, every 15 or 18 inches apart, are fixed circular discs about 2 inches in diameter. The upgoing-side of the endless chain is inside an iron pipe, the diameter of which is slightly greater than that of the discs. To the pulley is affixed a crank-handle, which, when turned at an ordinary speed, carries the water up the tube to the desired height. This class of pump works best with lifts under 12 feet; over that it is heavy to work. Loose straws or mud do not in any way interfere with its proper working, and it lasts for many years without any renewal.

Dispensing with Pumps.—If the configuration of the land will permit of such, tanks should always be emptied by a pipe direct from the bottom to some place on a lower level, but high enough to run into a cart. Much labour is thereby saved, and not a little time. Cast-iron pipes are the best for the purpose, as fireclay ones can rarely be made tight enough at the joints to bear the requisite pressure.

Size of Tank required.—To know

the size of tank required for any particular case, an allowance of 1000 gallons for every cow on a dairy farm will suffice, and that number of gallons occupies 162 cubic feet. When enlarged tanks are desired, it is better, because cheaper, to have parallel rows of narrow tanks contiguous to each other, than to extend the breadth or length, or increase the depth. In a series of parallel tanks, the common walls support the arches on both sides. A tank of 72 feet in length, 6 feet wide inside, and 6 feet deep below the soles of the drains, contains about 2600 cubic feet.

A Mid-Lothian System.—A simple and convenient mode of collecting the liquid manure of a dairy farm—of from 130 to 170 acres, with a stock of cows from 14 to 24, with young beasts and horses—has long been practised in Mid-Lothian. Drains are formed from the byres and stables into one main drain, the mouth of which is elevated as high above the ground below it as to admit a liquid-manure barrel—a common butt, mounted on its cart—to stand under it, and receive the liquid direct into the bung-hole; and as the barrel becomes full, it is carried away, and its contents emptied on the field. The barrel contains 150 gallons, and is usually filled three times a-week. When there is an excess of liquid, in consequence of much rain, it is allowed to run into the dunghills below the drain, and after saturating them it flows into an open shallow tank, from which it irrigates at pleasure a drained moss laid down to perpetual grass. A common butt, of 150 gallons, sunk into the ground, forms a good tank for a labourer's cottage, and, retaining all liquid refuse, affords a ready means of manuring a portion of the garden.

Incorporating the Liquid with the Dung.—We may say at once that we think the best way of utilising liquid manure is incorporation with the solid manure, and that therefore the liquid manure which finds its way into the tanks should in the first place be used in saturating the drier portions of the dung-heap—that is, in so far as it can be readily absorbed and held by the solid material.

Where this practice prevails, a convenient arrangement is to have in each

court a tank into which any liquid that escapes from the dung finds its way—a tank sunk in at the lowest point in the court, with access for the liquid manure through a grating. A pump rises up from the tank, and once every week the cattle-man pumps the liquid back over the dung, directing it by movable spouts of various lengths on to the drier parts of the dung-heap. This is a capital plan both for the solid and the liquid manure, and by it the maximum quantity of first-class dung may be made.

Of course the extent to which this plan may be advantageously carried out will depend largely upon the supply of litter. If there should be plenty of litter, the whole of the liquid manure may be fully and most profitably utilised in this way—that is, where the liquid manure is not increased to excess by rain-water. On the other hand, where litter is scarce and the dung therefore short in texture, it may not be able to absorb nearly all the liquid manure.

Utilisation of Surplus Liquid.—There will thus in many cases be more liquid manure than can be advantageously absorbed by the dung. This indeed will rarely happen where the cattle-courts are roofed and any extraneous water prevented from reaching the dung, but it will very often occur where the greater part of the cattle-court or dung-pits is uncovered. Now the profitable preservation and utilisation of this *surplus* liquid manure are the two most important points in connection with what is generally known as the liquid-manure question.

In reference to this economical utilisation of liquid manure, some remarks well worthy of careful attention were made by Professor R. P. Wright, Principal of the West of Scotland Agricultural College, Glasgow, in a paper in the *Farming World Year-Book*, 1889, from which we have made copious extracts.

Noteworthy Attempts.—Professor Wright says: “It is not surprising that the problem of the economical utilisation of a manure possessing such high qualities as have been described, and which is regarded by many as the most valuable of all manures, should have engaged the attention of some of the most enterprising agriculturists of this century, and

that numerous attempts should have been made to overcome the difficulties attending its practical application.

“Perhaps the most widely known investigator into this question was the late Mr Mechi of Tiptree Hall; and further attempts, modelled on the practice recommended by him, were made at Myrie Mill and Kinning Park, in South Ayrshire. The efforts made on these farms to secure the complete and effective distribution of the liquid manure by means of elaborate arrangements of pipes, conduits, hydrants, and other machinery, were continued over a series of years, and have furnished sufficiently conclusive proof that the thorough distribution and utilisation of the whole quantity of liquid manure produced on a farm is perfectly possible, and they have further shown that the expectations entertained of the effects of the liquid dressings have been in no degree exaggerated, and that by judicious applications crops of wonderful luxuriance can be successfully grown.

Outlay greater than the Return.—

“But the ultimate collapse of these systems of farming has just as completely demonstrated that, however remarkable the results obtained from the use of liquid manure, the return is not sufficient to defray the expenditure. Mr Mechi, indeed, is said to have maintained to the last that his practice was profitable; but it is now almost universally held that the bulk of material to be disposed of in liquid manure wholly rules the economy of its use, and that with the low average prices of the farm crops for which it is best suited, no method of utilising it can be profitable unless the outlay involved be reduced to a very low point. Any costly process of treatment must be looked on as unlikely to yield a satisfactory remuneration.

Suitable for Exceptional Crops.—

“It must not be forgotten, however, that this objection does not hold good when the liquid manure is employed for crops of relatively high value. Expensive methods of application may be justifiable for the production of certain market-gardening crops, or even some common farm crops grown in a district of high markets; but for ordinary farm practice it may be fairly concluded that only such

modes of utilising liquid manure are commendable as involve the minimum of expenditure."

Application by Cart.—In discussing the various methods of applying manure, which have been found most successful and been most largely adopted, Professor Wright says: "Perhaps the best known and most widely adopted practice is to collect the liquid manure in a central tank or reservoir, to pump the liquid at intervals into a specially constructed manure-cart, and by its means to spread the liquid over the land. The initial expense is confined to the provision of a tank, of a pump, and of a manure-distributor; and the amount will vary according to the dimensions and extent of building needed, and the size of the pump and distributor. The after-cost is limited to the charge made for the man and horse required for the conveyance of the manure to the fields; and this may properly be estimated at a low rate, as such work can be done, in part at least, at odd intervals of time.

"Although this plan of utilising the manure is pretty common in some districts of the country, it cannot be regarded as a very satisfactory one. The first expense is not inconsiderable, and the manner of applying the manure does not warrant the expectation of the most favourable results. The operations of pumping and carting such large quantities of liquid are slow, cumbrous, and troublesome, and in the press of other farm-work the dressings are apt to be given at irregular intervals, and perhaps at unsuitable times. Very often the liquid so applied is not sufficiently diluted, when it is liable to injure and destroy the vegetation. There is a constant temptation to use the manure in a strongly concentrated form, because any addition of water entails some additional difficulty, and the greater the dilution the heavier becomes the subsequent labour of pumping, carting, and spreading.

"For these reasons, while this practice prevails somewhat widely, it has never obtained a very great popularity among

farmers. Many of them, however, hold decidedly the opinion that, whatever be its other drawbacks, it has the crowning merit of being thoroughly profitable, and of far more than repaying the cost of application."

Fig. 339 represents a liquid-manure cart (Coleman & Morton, Chelmsford),

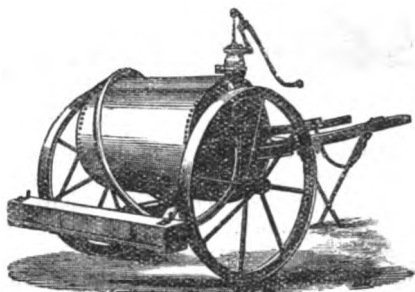


Fig. 339.—Liquid-manure cart.

which has attached to itself a pump and pipe with which to raise the liquid out of the tank. A new and ingenious form of liquid-manure cart, invented by a farmer near Wishaw, Mr D. Macpherson, is shown in fig. 340. As the

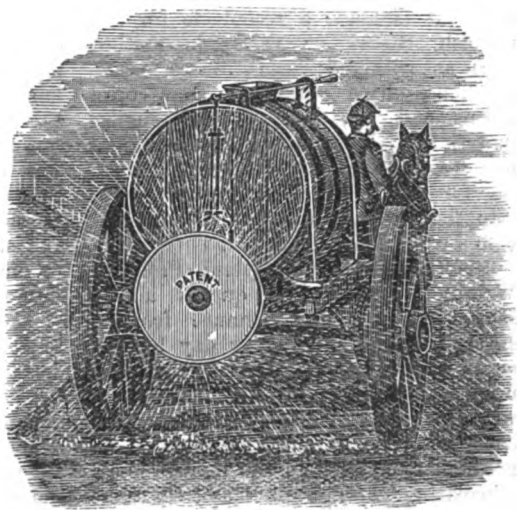


Fig. 340.—New liquid-manure cart.

liquid escapes from the barrel of the cart it is caught by a revolving disc (driven by a chain from the axle of the cart) with several equidistant flanges, and is sent over the ground in an even spray as shown in the figure. It spreads

the liquid evenly, and takes a breadth of about 30 feet at a time.

Various other forms of liquid-manure carts are used. Where the liquid cannot be pumped it may be conveyed to the cart by a scoop such as that shown in fig. 341, a wooden pitcher about 8 inches



Fig. 341.—Scoop for filling a water-barrel.

in depth and 10 inches in diameter, the helve passing through its sides in an oblique direction, and a little above its centre of gravity.

Making Compost with Liquid Manure.—In many cases the surplus liquid manure, instead of being collected into a tank, is directed by a channel—in some cases open, in others covered, as it always should be—into a compost-pit. On many farms this pit is merely a convenient hollow near the steading, but where there is a good deal of surplus liquid manure it will be profitable to have a properly constructed reservoir. This pit is made a receptacle for dry rubbish, earthy or vegetable matter, such as withered weeds, waste straw, brackens, dried scrapings from open drains and roadways, or any similar material capable of absorbing the liquid manure and then forming useful dressing for land. The liquid manure runs into this pit, and converts the dry rubbish into valuable compost.

Referring to this system Professor Wright, in the paper quoted above, says: "The liquid manure from a steading running regularly day by day on to such a body of dry material gradually works into it, till ultimately the waste becomes so much enriched by the constant deposition of the valuable ingredients contained in the liquid slowly percolating through its mass, as to be converted into a manure, not inferior in its character and qualities to ordinary farmyard manure, and requiring a similar after-treatment and management.

Advantages of the Compost System.—"This system appears to possess many valuable features, and to be preferable to that previously described. It

allows of the utilisation of quantities of organic material, which otherwise might have been got rid of by burning or some other equally profitless method. It gives the farmer the command of what is practically an additional supply of farmyard manure. It is capable of being adopted on farms in any situation, and it permits the application of the fertilising substances of the manure to a greater variety of crops than can be conveniently or beneficially treated with any manure in a liquid form.

"It is a cheap method, as reservoirs may be dispensed with entirely, or may be of the crudest kind, while the expense of forming conducting channels is trivial. It is particularly suitable where the liquid manure is of a strongly concentrated character, and it is free from any of the drawbacks that attend the direct use of the liquid in such a condition.

Amount of Carting.—"The only objection that can be taken to this practice is on the ground of the amount of carting required. It is to be remembered, however, that the carting of large quantities of dry rubbish is a comparatively easy matter, owing to its light weight; and, on the other hand, the manure produced would be worthless indeed, did it not more than handsomely repay the labour of conveying it out again to the fields."

Forming a Compost Reservoir.—The receptacle for the liquid-manure compost need not be costly or elaborate. It should be water-tight at the bottom and sides. Concrete or masonry would be most substantial, but it might be formed merely of earth with a coating of clay pounded into the sides and bottom. It may be from 2½ to 3 feet deep, and at one end should slope up to the level of the ground, so as to provide easy access and egress for carts.

Irrigation with Liquid Manure.—Where the configuration of the land and the system of cropping are suitable, and a stream of water available, this is an excellent method of utilising liquid manure. The liquid as it escapes from the steading is conducted into a small stream, which is controlled for the purpose, and which is then employed in irrigating an adjoining meadow. Professor Wright says: "This practice is less known than

it ought to be. In those districts in which it is carried on, its benefits are well understood and thoroughly appreciated. It combines at once all the advantages of water irrigation with those of ordinary manuring. It secures the employment of the liquid manure in its most highly diluted and most effective and favourable form, while the water from the stream may itself contain no inconsiderable portion of fertilising ingredients. It allows the manure to be used on the crop, grass or hay, for which it is best suited, and on which it will give the largest increase.

"The fullest fertilising effects are obtained from this system, because there are no hindrances in the way of the most regular and periodical applications of the manure, and because the thickly matting roots of the grasses do not permit the escape to the drains of any of the valuable substances. It is the cheapest of methods, as there is no expense further than cutting the small channels and watercourses, and keeping them in repair. No horse labour is required, and only a very slight attention is necessary to keep the whole system in good and regular working order."

As will be readily understood, the circumstances necessary for the success of this method of irrigation are of rare occurrence, but wherever they do exist they should be taken advantage of; for Professor Wright adds, "I have never yet met a farmer who had given it a trial who has not had reason to be perfectly satisfied with the results."

Preventing Loss of Ammonia.—Wherever liquid manure collects there is risk of loss by evaporation of its ammonia. This, however, may be prevented by sprinkling gypsum over the liquid in the tank, or on the liquid manure wherever it may be collected or exposed. Some experienced farmers have a gypsum-box kept constantly in a corner of the byre, and immediately after the byre is cleansed a little of the gypsum is sprinkled over the fresh dung and on the spaces behind the cattle. The gypsum "fixes" the ammonia, and thus prevents its evaporation. This practice is a most commendable one. It causes little extra labour, and may save considerable loss of the most costly of all manurial ingredients.

The gypsum-box should be at every steading, and its contents should be used with unfailing regularity, not only for the liquid manure tanks but also for the dung-heap itself.

The Problem solved in Sussex.—Professor Wrightson makes favourable reference to an ingenious method adopted by Mr Livesey, C.E., in his beautifully constructed cow-house at the Mayfield Dairy, Rotherfield, Sussex. So as to avoid the necessity of litter, and to effectually conserve both the solid and liquid manure, Mr Livesey had a gutter, 2 feet wide and 5 inches deep, made behind the cows. This gutter is nearly filled with dry earth *sprinkled over with gypsum*, and this porous matter receives both the solid and liquid excrements of the animals. Guide-rails are laid in the passage behind the gutter, and the soil is daily removed and collected in a shed adjoining. Mr Livesey regards the material thus collected as, weight for weight, three times the value of ordinary farmyard manure made in his district.¹

This system must, of course, involve a good deal of extra labour, but such advantages as are claimed for it would most probably far outweigh the increased expense. The practice, it will be observed, not only utilises the whole of the liquid manure in a most effective manner, but also renders litter unnecessary, which is in itself a point of great importance.

Fresh Urine injurious to Vegetation.—If urine is applied to grass-land or to growing crops while the urea is undecomposed, or the ammonia is in a caustic state, it will destroy vegetation. When intended for direct application to crops, the liquid should therefore be allowed to "ripen" for some time—perhaps four or five weeks in summer, and eight or nine in winter; or by the addition of a little sulphuric acid, the caustic ammonia may be turned into a neutral salt—sulphate of ammonia,—and if thus prepared, liquid manure may at any time be applied with safety. (Read in this connection what is said as to the composition of fresh and stale urine, and the changes the liquid manure undergoes by keeping, pp. 476, 477.) But fresh urine may safely be applied to the ploughed

¹ *Agric. Gazette*, 1888, p. 464.

soil at any time, in as far as the soil is concerned, although it is better received by the soil in some states than in others.

Time for Application.—Early spring is considered the best season for applying the liquid manure, not only because it is then most abundant, but the ground, being all ploughed, is then also in the best state for imbibing it: and if applied to the soil just as it has flowed into the tank,

much trouble will afterwards be saved in driving out the water, which must be put amongst it to save the ammonia, and which in fact is better saved by the humus of the soil. Formerly winter was considered the best time for applying liquid manure; but the Rothamsted investigations as to the loss of nitrates through drain-water from land not covered with any crop have shown that this was an error.

ARTIFICIAL AND SPECIAL MANURES.

Attention will now be given to the various artificial or special manures which are used to supply one or more of the ingredients necessary for the growth of plants.

Classification of Artificial Manures.—These are classified in accordance with the proportion of the more valuable or abundant constituents present in them, and they are accordingly divided into the following groups: nitrogenous, phosphatic, potassic, calcareous manures.

Peruvian Guano.

The chief of the nitrogenous manures was formerly guano in its various forms.

In the year 1839 some twenty barrels of a red or light-brown substance were imported into Liverpool from one of the islands which lie adjacent to the Peruvian coast. The substance had been in use as a manure amongst the natives of Peru for many centuries. It became known as guano, a term which takes its origin from the Peruvian word "huana," dung or manure, which consists of the accumulated droppings of sea-fowls during long periods of time.

As the temperature stands very high in those regions (lying between 13° and 21° south latitude), these bird-droppings soon dry; and as the climate is almost a rainless one, much of the soluble ingredients are preserved.

The resulting manure is a complex one, possessing a composition similar to farmyard manure. After experiment, and when the merits of the guano were brought home to the mind of the

farmer, the demand for it rose very quickly.

We can form some idea of the estimation in which this manure was held by the Peruvians from the proverb, "Huano, though no saint, works many miracles"; and from the fact that, under the government of the Incas, the killing of birds which frequented the islets in which guano deposits were formed was made a capital offence.

When the exportation attained considerable proportions, the Peruvian Government, by exercising its lordship of the soil, created a monopoly of the sale of guano, which was sold at so much per ton irrespective of quality. The first contract made by British merchants was in 1840 or 1841. They made it a condition of the contract that for a period of four years they would have the exclusive right to export from the island of "Chincha" 20,000 tons of guano yearly.

The increasing demand and the monopoly, which raised the price of guano above its real value, together with the fact of the richer deposits becoming exhausted, led to guano being sold on analysis. This arrangement is still in existence; and as a consequence, it is customary for sellers to attempt to sell cargoes upon "official analysis."

From the year 1850 to 1870 there was a large increase in the demand for guano, as many as 200,000 tons having been imported in a single season. The quality of the Peruvian deposits was yearly deteriorating, and accordingly other coasts

were explored, resulting in the discovery of deposits in the African coast which lies between these latitudes. Ichaboe was the richest, and Mejillones the poorest. These two guanos are fair representatives of what is known in the trade as high-class and low-class guanos. The one contains a large percentage of

ammonia and a low percentage of phosphates; the other a high percentage of phosphates and a low percentage of ammonia or none at all.

Composition of Guanos.—The following may be considered as average analyses of the guanos of the present day:—

	Raw Peruvian as imported.			Raw Peruvian "Blended."	"Peruvian Equalised."	"Peruvian Dissolved."	Raw Ichaboe.
	BALLESTAS Island.	PACHACAMAC.	Lobos de Afuera.				
Ammonia .	10.13	4.97	2.92	7 to 8	8	7	13.0
Phosphates .	28.70	30.59	41.63	30 to 35	25	*22	11.0
Potash .	2.85	3.42	2.68	2	2	1½	2.

* 18 Soluble.

Although the old deposits of highly ammoniacal Peruvian guano are exhausted, fresh quantities of new formation occur to-day and are removed from time to time. That from Ballestas Island is such a modern deposit.

Mejillones is purely phosphatic, and is a low-class guano. It is not now imported into this country. The latter term, however, embraces guanos which contain anything under 4 per cent ammonia and over 40 per cent phosphates. The absence of ammonia is due to these guanos being deposited in climates where frequent and heavy rains occur. These heavy rains supply the moisture necessary to set up fermentation in the guano, and they wash away the soluble salts and ammonia which are the products of this fermentation.

Fish Guano.

Formerly there was great loss of fish-offal. In many cases no attempt was made to utilise this offal, which, besides the heads and entrails of all the larger fish, and the cleanings of the herring-curing stations, often included large quantities of entire herring which the curers were unable to manipulate. Neighbouring farmers bought large portions of this offal; but frequently they could not use up the supplies, so that many boat-loads of fish were emptied into the sea as being the only means of getting rid of the material.

Such excessive waste could not long continue in the light of the nineteenth century. At length, at the various fishing-stations, factories were erected in which the offal is submitted to the

action of steam at a high pressure, and afterwards it passes through the hydraulic press, by which means the greater portion of the oil is extracted. The whole mass is next passed through the disintegrator, and thus is produced the article known as *fish guano*.

Composition of Fish Guano.—The composition of fish guano usually varies from 7 to 8 per cent of nitrogen (10 to 12 per cent of ammonia), and from 6 to 30 per cent of phosphates. The fish guano in the market seldom contains more than about 9 or 10 per cent of ammonia and 16 to 20 per cent of phosphates. But there is also present oil, which detracts from the value of this manure, as the oil retards the dissolving of the elements of plant nutrition which the fish guano contains. The best samples are those from which the bulk of the oil has been removed, containing only about 3 per cent of oil.

Frey Bentos Guano.

In the manufacture of Liebig's extract of meat there is a large residue of flesh, bone, and muscle. These substances are mixed together, dried, and ground, the product being a flesh guano, if we may so term it. In other instances a large supply is obtained from diseased meat and animal refuse of all kinds.

Composition.—The composition of flesh guano varies from about 8 to 13 per cent ammonia, and from about 10 to 20 per cent phosphates. But when bone refuse predominates in them they more nearly correspond with bone in composition.

Dissolved Guanos.

The unequal character of natural guano in recent years has led to its being treated with sulphuric acid, and its composition being otherwise altered by the introduction of ammonia from sulphate of ammonia, dried blood, or other organic source. This process dissolves the phosphates and organic matter, making these more soluble, and the nitrogenous matter raises the percentage of ammonia, so that an active manure is the result. This commodity is known as Dissolved Peruvian Guano.

Composition.—Dissolved Peruvian guano is generally in good mechanical condition. It usually contains 7 per cent of ammonia, and 22 per cent of phosphates, of which 18 are soluble.

Dried Blood, Shoddy, Rape-dust, &c.

Dried blood, horn-dust, shoddy, and other waste products from the shambles or factory, and also ground oil-cakes like rape-dust, may all be treated as insoluble nitrogenous substances, coming into action comparatively slowly. They contain nitrogen equal to from 5 to 18 per cent of ammonia. They are used principally in the manufacture of dissolved and compound manures, and contribute to the percentage of ammonia in these, but are sometimes used directly, especially in hop culture and market-gardening.

Nitrate of Soda.

Nitrate of soda, otherwise known as Chili saltpetre or cubic nitre, is the most abundant and best known of the nitrates.

This salt is a natural product of the soil in tropical climates, and as to its formation, several theories, less or more different, are entertained. A full description or discussion of these theories need not be attempted here. Some hold that it is made from the action of water, impregnated with soda salts upon guano. Others attribute its formation to seaweeds, which, by their decay, have given rise to nitrate of lime, which reacted upon sulphate of soda, the products being nitrate of soda and sulphate of lime. It is supposed that these beds were at one time isolated lagoons—isolated by volcanic action. The sea-water on its evap-

oration would leave a large salt deposit, thus furnishing the source of the great quantity of soda salts found in these nitrate beds. The lime would, according to this sea-weed theory, be supplied by sea-shells, &c.

The chief sources of supply are Chili, Peru, and Bolivia, where it occurs in beds varying from 10 inches to 16 feet in depth, sometimes quite near the surface, but generally covered by several feet of a layer known as "Costra." The regions in which nitrate of soda is found are quite destitute of vegetation, and there is often a period of several years without rain. These beds lie in the Pampas known as "Los Salinas," which is over 40 leagues in extent, and literally covered with beds of nitrate of soda.

The supply, though it cannot be regarded as inexhaustible, bids fair to last for a great many years yet, despite the constantly increasing demand. In its native state the nitrate is mixed with impurities, notably chloride of sodium (common salt) and sulphate of potash, soda, lime, &c. But before exportation it undergoes a process of refining which renders it comparatively pure, 5 per cent being about the amount of impurities remaining in it.

Nitrate of soda, when first introduced as an artificial manure, came into great repute amongst farmers as a fertiliser. Its high price, however, and the lack of correct views as to its action and unsound mode of application, brought it into such ill favour that on some estates its use as a manure was in certain circumstances prohibited.

In recent years, however, with more enlightened views as to its character and action, this prejudice has passed away, and a steady increase in the demand has arisen. Indeed, this salt is to a large extent, as a source of nitrogen, taking the place of that now more variable commodity Peruvian guano. We find that in the year 1880, 50,000 tons of nitrate of soda were imported, while in 1907 the imports exceeded 100,000 tons. The total output of nitrate from Chili in 1906 was 1,719,600 tons. It must be remembered, however, that a large proportion of this is used for industrial purposes outside of agriculture—such as the manufactures of nitric acid for

dynamite, &c. Nitrate of soda usually consists of 95 per cent pure nitrate of soda, which contains 15.6 nitrogen, equal to about 19 per cent of ammonia.

Recently the manufacture of nitrate of lime has been begun in Norway, from nitric acid produced electrically from the atmosphere by means of a "flaming arc" discharge of an electric current generated by water-power. The process has not been in use long enough to allow of a demonstration of its ability to continuously produce nitrate at a price to compete with natural nitrate. But it has gone sufficiently far to afford sanguine hopes that in the future, if not at once, we may look to atmospheric nitrogen as a commercial source of plant-food.

Calcium Cyanamide.

While speaking of electric utilisation of atmospheric nitrogen to produce nitrates, we may here refer to a quite different form of nitrogenous manure recently manufactured by electric heat from atmospheric air—viz., calcium cyanamide. Calcium carbide is made by fusing lime and coke in the electric furnace, and when nitrogen is passed over the heated carbide, a compound called calcium cyanamide is produced. This, when ground and mixed with the soil, gives off its nitrogen in the form of ammonia. The evolution is gradual, and is dependent upon moisture and other soil conditions, and the action of the manure is uncertain, though in some experiments it has nearly equalled a corresponding quantity of sulphate of ammonia—to which, however, it must be regarded as inferior, on account of its greater uncertainty. It contains about 19 per cent of nitrogen.

Nitrate of Potash.

This salt is much more valuable than nitrate of soda, both commercially and from an agricultural standpoint. Nitrate of soda supplies only one of the ingredients of plant-food, whilst nitrate of potash provides two—nitrogen and potash,—and is a valuable manure where applied to soils poor in clay and where no farmyard manure has been applied.

Nitrate of potash has been imported from India for many years, it being the nitre or saltpetre of commerce. The source of this Indian nitrate of potash

is believed to be human urine which had at some time been poured upon the soil, these nitre-beds being found near the sites of ancient cities. Until lately its high price prevented farmers from using it as a manure.

It is, however, produced by artificial means, which is of interest to farmers, as seen in the nitre-beds or saltpetre plantations which originated in France during the last century so as to obtain a supply of nitre for the manufacture of gunpowder. The manner in which this nitre is produced ought to be studied by every farmer, as he is in many instances, perhaps unknown to himself, producing this salt in the soil of his farm.

Forming Nitre-beds.—A brief description of how nitre-beds are formed will place the matter clearly before our readers. A quantity of fertile loam is procured, and with it is incorporated highly nitrogenous organic matter—such as blood, flesh, liquid manure, stable manure, &c. To this is added chalk or old mortar-lime, and the whole mass turned over once or twice, after which the soil is washed and the water evaporated, when the residue is found to be crystals of nitrate of potash.

The chemical changes which here take place are as follows: The decay of organic matter is hastened by the lime, and produces nitric acid. Ammonia is produced, and becoming oxidised it is converted into nitric acid, which combines with the lime in the first instance, and afterwards with the liberated potash, and thus is evolved the nitrate of potash.

Nitrate of potash of 95 per cent purity contains 13.1 per cent of nitrogen, equivalent to 15.9 per cent of ammonia.

Nitrification.

Theory of Nitrification.—The explanation of nitrification is that organic matter, when it is allowed free contact with the air and moisture within certain ranges of temperature, undergoes changes which break it up into simple bodies. This result is produced by the presence of myriads of minute organisms termed "bacteria." These living bodies feed upon the nitrogenous matter, and increase in numbers at a rate of which we can have but little conception. Every

fertile soil, therefore, becomes the home of countless millions of these living organisms which carry on the work of nitrification, so that, as Professor Cohn tersely puts it, "Putrefaction is the concomitant not of death but of life." The nitrogen of the organic matter is first converted by bacterial agency into ammonia, then into nitrites, which in turn are converted into nitrates, each stage being accomplished by the work of a different set of organisms.

Conditions which favour Nitrification.—The conditions necessary for the life and development of the nitrification ferment are,—(a) temperature above 40° Fahrenheit and under 130° Fahrenheit—most favourable temperature, 100° Fahrenheit, development at that temperature being as great in a few days as in months at a lower; (b) a certain amount of moisture; (c) presence of organic matter, mineral constituents of plant-food, carbonate of lime, and a plentiful supply of oxygen. Any excess of putrefying organic matter in a soil is against nitrification. It is found to be most active near the surface of the soil; it is not found much below 18 inches. Strong sunlight is not so favourable as darkness. The bacteria are easily killed by poisons, such as ferrous sulphate, coal-tar, and sulphuretted hydrogen.

Sulphate of Ammonia.

Until recently, the chief source from which sulphate of ammonia was obtained was a by-product from the distillation of coal in the manufacture of gas. The ammonia set free is absorbed in water at a low temperature, which, on being heated by steam, gives off the ammonia, which is received in vessels containing sulphuric acid. These enter into combination, and sulphate of ammonia is the result. Pure samples contain from 19.8 to 20.6 per cent of nitrogen, equal to 24 or 25 per cent of ammonia.

Another source of supply, which appears to be almost without limit, is from the coal burnt in furnaces of iron works and other factories, and from coke ovens. Sulphate of ammonia is also obtained in the conversion of shale into paraffin-oil. The production has been largely increased by, if it has not been alto-

gether due to, the introduction of Young and Beilby's retort in oil-works. The process by which the sulphate is produced is similar to that carried out at the gas-works.

The preceding are the chief nitrogenous manures which are at present marketable commodities. Other substances might be mentioned, but they are either too expensive for use as manures, or contain their organic matter in such insoluble compounds as to be practically worthless.

Characteristics of Nitrogenous Manures.

There are a few points in connection with manures which should be carefully considered by farmers, so that they may be guided to a wise selection of manures to suit their varied circumstances as to soil, climate, and crop.

Essential Points.—It should in particular be borne in mind, (1) that the solubility of a manure depends on the minute division of its parts; (2) that the greater the solubility, the quicker its action; (3) that the shorter the time a crop occupies the ground, the more abundant and the more soluble must be the manure; and (4) that the rate of the growth of a crop ought to indicate the kind of manure, and the best state in which to apply it.

If these points are kept in view, the classification of manures in relation to their activity, and their action on the crop and in the soil, will be comparatively easy.

Slow and Active Manures.—A manure may, however, be immediately perfectly soluble and yet not be available to the plant. It depends on the form in which its elements are combined whether the plant will absorb it or not.

For instance, nitrate of soda and sulphate of ammonia are equally soluble salts, but both are not alike available for plant-food. Nitrate being a compound of nitric acid and an alkaline base, is readily absorbed and elaborated into the tissues of the plant; whilst, at any rate to most plants, sulphate of ammonia is not available until the ammonia absorbs oxygen, and is converted into nitric acid. The latter, therefore, does not come into action so quickly, and ought to be applied to the land before the plant

is ready to absorb it. Nitrate of soda, on the other hand, is most economically applied after the plant has developed its leaf-surface to a greater or less extent.

Assimilation of Ammonia by Plants.—It is considered by some to be too sweeping an assertion to say that ammonia is not in any case available to plants until it is converted into nitric acid. It is admitted that most plants assimilate their nitrogen in the form of nitrates; but that some plants, more especially at certain periods of growth, have the power of assimilating their nitrogen in the form of ammonia would seem to be indicated by certain experiments by Lehmann.

Action of Nitrate of Soda.—Nitrate of soda, as will be seen further on, is feebly retained by the soil, and should therefore be applied only to supply the wants of the crop then growing. The surplus will find its way to the subsoil, and may escape in the drainage-water. It exhausts the soil more quickly than any other manure, *if the soil is unaided by the application of other manures*. The reason of this is, that its action in the first instance tends to increase the leaf-surface of crops, which therefore make larger demands upon the soluble constituents of the soil, resulting in a heavier yield per acre. But if care is taken to have the soil sufficiently furnished with the other elements of plant-food, this exhausting influence of the nitrate may be effectually counteracted.

In a dry season, nitrate of soda gives better results than sulphate of ammonia, and increases the produce of straw as well as of grain. When applied to grass without a corresponding supply of phosphates and potash, nitrate of soda checks the growth of clover by unduly favouring the true grasses, and therefore in manuring grass-land a well-balanced mixture of manures should always be given.

Nitrate of Soda and Sulphate of Ammonia Compared.—We have seen that sulphate of ammonia contains considerably more nitrogen than nitrate of soda, the most general proportion being about 20 in the former to about 15.6 in the latter. Experience, however, has shown that the nitrogen in the nitrate of soda is the more effective, producing at Rothamsted and Woburn about 14

per cent more barley, and from about 5 to 25 per cent more wheat, than sulphate of ammonia; while, when applied with potash salts and phosphates to grass-hay and potatoes, similar results were obtained. When applied alone, the nitrate of soda was far superior to the sulphate of ammonia. With mangels the evidence in favour of nitrate of soda has been still more striking. It may thus be taken as fully established, that although sulphate of ammonia may contain nearly one-third more nitrogen than nitrate of soda, it is not, as a rule, worth to the farmer more than from one-tenth to one-eighth more money per ton.

Nitrate of soda is better suited for soils poor in lime than sulphate of ammonia, as the latter tends towards lime exhaustion. If sulphate of ammonia is frequently used on soils poor in lime, applications of lime will be necessary from time to time to prevent an acid condition of the soil being brought about. Furthermore, ammonia-salts do not nitrify freely in absence of lime.

Guano, when of fairly good quality, gives better results than either nitrate of soda or sulphate of ammonia used alone.

Soot.

Soot is chiefly valuable for the sulphate of ammonia it contains—usually, in good samples, about 20 per cent, giving 4 per cent of nitrogen or 5 of ammonia. But the quantity is very variable, and largely depends on the admixture of ashes or “flue-dust,” and on the nature of the coal from which it is produced. Soot is claimed by many practical men to have an excellent mechanical value on stiff clay land.

Excessive Nitrogenous Applications Injurious.—The excessive application of nitrogenous manure tends to increase the percentage of nitrogen and diminish that of phosphoric acid in the composition of plants. This fact leads to wide issues; for the relation between the soil and plant is in no way closer than that between plants and animals. From this cause we have weed and diabetes in horses, and, where phosphates are deficient, rickets, rotten teeth, and late dentition, &c.

Nitrogenous Salts are not suited for grain crops when applied alone, as the

tendency is to produce straw at the expense of the grain. But when these are mixed with phosphates, excellent results are obtained.

Slow Manures for Slow Crops.—The period of time during which the crop occupies the ground has a considerable influence upon the economical use of soluble manures. Wheat takes often seven to nine months to mature, and during that period will have plenty of time to use up the soil constituents which are slowly soluble. Barley, on the other hand, is often harvested in four months or less; so that this cereal, being a shallow-rooted plant, will require readily soluble manure in greater abundance. For this reason, top-dressing once or twice with any of the more soluble nitrogenous manures, mixed with superphosphates, would give the best results; for it must be kept in view that crops can take up nitrates only when soluble phosphates and potash are present.

Action of Guano.—Guano is both a quick- and a slow-acting manure. The ammonia present in guano is to the extent of one-third or more in the form of salts which are readily soluble; the other portion is in the form of compounds more or less soluble. Its phosphates are of secondary consideration; but when guano of good quality can be obtained, it is undoubtedly the best manure in the hands of the farmer—that is, next to farmyard manure. Its use has now become limited by its scarcity and very variable composition.

Horn, Dried Blood, Shoddy, Wool-waste, &c., are very slowly acting manures, and are, in consequence, more fitted for pasture-land or for hops than for quick-growing crops. But in a dry season they may prove as effective on the root crops as the more soluble forms. They are used chiefly to fortify dissolved manures.

Power of Soils to retain Manures.—In connection with the more soluble manures, one should not overlook the fact that some soils have a greater power of retaining manures than others, and that some manures part with one or more of their elements more readily than others. The power of a soil to retain manure was at one time thought to be a mere physical property pertaining to it, but later re-

search has modified that opinion. Way, in the *Journal of the Royal Agricultural Society of England*, clearly proved by experiment that when solutions of the various salts are filtered through a layer of earth, and the solution, after filtration, is analysed, it is found to have lost all or nearly all the substances which it held in solution—it being the base rather than the acid which the soil had the power of retaining. This affinity is greater in some soils than in others, the following being the order: arable soil—clay, peaty, calcareous, sandy. It has also been found that the soil has a greater power of retaining some manures than others, the following being the order, those having the greater affinity being placed first: ammonia, potash, magnesia, lime, soda.

In explanation of this, Way advanced the following theory: In soils there are double silicates of lime and alumina. If potash be brought into contact with this double silicate, it replaces the lime; sulphate of lime and the double silicate of potash and alumina are produced. Silicate of alumina combines readily with ammonia, and least so with soda, &c.

Others, again, maintain that the oxide of iron, which is abundantly present in most soils, absorbs the ammonia. Warrington also found that this oxide acts upon superphosphates. The soluble phosphoric acid may also be retained by recombining with lime and forming a slowly soluble salt.

Conserving Manures in Soils.—All agree, however, that the soil has little or no power of retaining nitrates in any combination. We must therefore look to some other means to preserve this valuable manure. The growth of catch crops has been recommended for this purpose. But this is impracticable in many instances, such as in ploughed land preparatory to the turnip crop. The work of the farm must go on in a regular manner, and the leaving of the fallow unploughed until spring would throw the work into confusion. Where the land can be kept under crop of any kind this should certainly be done, for the nitrates will be preserved by being absorbed by the roots and elaborated into the tissues of the plants as albumen.

It seems, however, that in this as well as in many operations connected with agriculture, where the farmer fails nature steps in and provides a remedy. This may be understood when we are aware that nitrification proceeds in exact proportion to the rise or fall of temperature, being at a minimum during winter, and ceasing entirely about freezing-point. We thus see that, during the season of least growth, nitrates are not produced, or produced only in small quantity; but as the temperature rises, and growth begins, then the bacteria resume operations, increasing in their productive powers until they reach the maximum during summer when the heat is greatest, and at the period of the greatest growth, and when nitrogen is most largely required for the further development of the plants.

Action of Nitrogen greatest on Young Plants.—We learn from experiments conducted by Arendt that the presence of albuminoids, which are largely composed of nitrogen, is greatest during the first period of the growth of plants, and becomes a gradually diminishing quantity until it nearly reaches maturity. The beneficial action of a soluble form of nitrogen, such as in nitrate of soda, may be understood from this, especially when applied to young grass or corn crops when they come into braird.

Phosphatic Manures.

Bones.—The use of bones as a source of phosphoric acid and nitrogen for the growth of crops began long before the underlying principles of manuring were understood. The reason why an increase of crops should follow an application of bones was consequently the subject of many unsound theories.

Early use of Bone-manure.—The first authentic account we have of the use of bones in this country tells of their application in many parts of Yorkshire. Soon after they were applied to the exhausted pastures of Cheshire, the farmers of the latter county would seem to have fully appreciated the beneficial action of bones. Their active system of grazing with dairy cattle had greatly exhausted the phosphates of the soil, and the effect which followed a liberal dressing with bones was simply marvellous. Indeed the pastures to which they had been

applied very soon increased in value by 30s. per acre.

Fame of Bone-manure.—As would be expected, the story of this wonderful result rapidly attained notoriety, and led to an extended use of bones as manure in these districts. The small home-supply of bones soon became exhausted, and the importation of bones from Germany and Northern Europe speedily developed into a regular trade, of which Hull was the chief centre.

The bone-trade of Hull now became a leading factor in the agricultural world, and the benefits which arose to all classes in the community may be summed up in the proverb, "One ton of German bonedust saves the importation of ten tons of German corn."

Benefits from the use of Bone-manures.—But a direct increase in production was not the only benefit resulting from the use of bones as manure. The use of bone-manure played a leading part in the extension of turnip-culture, and in the consequent change of the whole system of farming formerly practised—changes which have led not only to a large increase in the production of food, but gave rise to that spirit of inquiry which has evolved and placed within our reach the mass of valuable information embraced in the term "Agricultural Chemistry."

Forms of Bone-manure.—Bones have been applied to the soil in many forms and conditions—raw or green, boiled, burned, broken, bruised, ground, fermented, and dissolved.

Raw Bones.—Raw bones vary in composition according to the kind of animal, its age, and the state of preservation of the bone.

The organic matter of bones is mainly composed of ossein or cartilage, which on boiling yields gelatine, largely used for the preparation of glue and size. It is this cartilaginous matter which yields the nitrogen which forms ammonia when "raw" bone is used for manure. There is also a varying quantity of fat in raw bone. As this is useful for soap-making, &c., and useless for manure, it is usual to remove the bulk of it by lightly boiling the bones before grinding them up for manure. Light boiling does not remove the cartilaginous matter, but

only the fat. At the present day what is known as English "raw" bone-meal is bone thus partially degraded.

The inorganic part of bones consists mainly of phosphate of lime with a small quantity of carbonate of lime, &c., with which is usually found a little sand accidentally gathered. The relative proportions of cartilage and inorganic matter vary in different kinds of animals, and in like animals at various ages. The bones of young animals generally are rich in cartilage as compared with those of adult animals; and the bones of horses are more cartilaginous than those of sheep and oxen. A vast quantity of bone-meal is made from imported bones. Sometimes these are bones collected in open plains from animals dying and decaying under the open sky. Their composition is affected by their age and condition. If they have lain too long they may lose much of their nitrogen by decomposition. Sometimes (as in the case of Indian bones) the effect of exposure to the jackals and vultures, and to the heat of the sun, is to cleanse the bones and free them from excess of grease, so that they are in a fit state for grinding into excellent manure without any preliminary boiling to remove grease.

Generally speaking, the higher the nitrogen in bones the lower the phosphates, and *vice versa*. Generally speaking, the nitrogen in good "raw" (or lightly boiled) bone-dust or bone-meal should be from $3\frac{1}{2}$ to 4 per cent (equal to $4\frac{1}{2}$ or 5 per cent of ammonia). Horse bone-meal may yield considerably more. The percentage of phosphate of lime should be from 40 to 50. It will more often vary from about 45 to about 50.

Preparing Bone-manure.—When bones were first used, they were simply chopped into pieces or broken by hammers. The advantage of their being broken was soon apparent, and mills were erected at nearly all the ports at which cargoes of foreign bones arrived. Steam-power was first employed in breaking bones by Mr Anderson of Dundee in 1829, his machinery preparing the bones in the form of $\frac{1}{2}$ -inch, $\frac{1}{4}$ -inch, and dust.

For some time farmers seemed to be satisfied with these sizes, as they considered that grinding the bones smaller detracted from their beneficial and last-

ing effect. The more observant, however, by watching the progress of their crops, noticed that the bone-dust came more quickly into action, and that it was mainly due to impurities that dust was not in favour. The dust being the small particles which passed through the riddles of the mills, would contain all the sand and earthy matter which would find a lodgment in the hollow parts of the bone; and much of the old bones which had lost part of their organic matter would also largely enter into the composition of this dust. Hence their inferior quality.

Fineness of Division appreciated.—The requirements of the turnip crop, however, increased the demand for quickly acting manure, so that farmers began to find out that the smaller the division the more soluble the manure. Thus bone-meal came into use, and has ever since remained the favourite form in which to apply bones to the soil.

Fermented Bones.—Before Liebig's discovery of dissolving bones with acid, various methods were tried to increase the solubility of bones, fermentation being one of many. It consists of mixing the bones with earth and saturating the mass with liquid manure, and allowing the heap to remain for a week or two before using. Some farmers in the present day ferment their bone-meal by throwing it into a heap after mixing it with water. In about a week the heat of the fermentation is at its greatest height, after which the heap will decrease in bulk and change in colour, the latter being due to the presence of insects and germ-life, which attack the organic portion of the bone and decompose it. There can be no doubt this process hastens the solubility of bones. But fine grinding, preceded by light boiling, is a sufficient treatment, having regard to the natural fermentative processes which occur in the soil—unless very rapid action is required, in which case acid treatment is resorted to.

Steamed or Degelatinised Bone-meal or Flour.—It has been already said that before converting raw bone into manure, the bone boiler generally removes the grease to make soap, thereby greatly improving the bone for manure, since fat retards decomposition in the soil. If the boiling be prolonged the

cartilage is gradually converted into soluble gelatine, a common source of glue. The degree to which the extraction of gelatine may be carried is variable, according to the process of boiling. Formerly it was common to extract about half the nitrogenous matter, and the residual bone was sold as "Boiled Bone." If this process was effected by high-pressure steam, the extraction was much more drastic, and then the residue was called "steamed bone." Now, however, there is little recognised distinction between "boiled" and "steamed" bone-meals. Indeed, since light boiling became usual in preparing "raw" bones for manure, the term "boiled" is no longer properly restrictable to glue-makers' refuse, and the term "steamed" or (better) "degelatinised" is now being applied to all grades of glue-makers' bones, the degree of degelatinisation being more plainly indicated by the simple guarantee of the percentages of nitrogen and phosphate present.

Steamed bone-flour undergoes a very searching process, as the bones are introduced into a Papin's digester, and submitted to the action of steam at a high

pressure, which removes a portion of, and in some instances nearly all, the organic matter, thereby disintegrating the substance of the bone, which is afterwards reduced to an impalpable powder. The abstracting of the gelatine decreases the manurial value, as it is the only source of nitrogen; but the percentage of phosphates and their availability, due to the fine state of division, are largely increased, which counterbalances this fact for certain uses. Fat is of no manurial value.

Burned Bones.—The burning of bones is a wasteful process to effect the same object. In this form they used to be largely imported from South America for the manufacture of superphosphates. In this process the nitrogen is entirely dissipated. No doubt it is a concentrated form in which to obtain phosphates, but the plan is not commendable. Bones are also partially burned to make animal charcoal for sugar-refining. The spent or exhausted "char" from the sugar factory is afterwards sold to manure makers to make superphosphate.

Analyses of Bone-meals.—The following are analyses of various samples:—

	English Bone-meal.		Indian Bone-meal.	Steamed or degelatinised Bone-flour or meal.		
	A.	B.				
Moisture . . .	7.54	7.68	7.90	11.00	6.88	11.10
*Organic matter . . .	25.06	37.20	27.94	12.94	8.44	10.24
**Phosphoric acid . . .	24.43	21.29	24.20	28.62	33.13	31.02
Lime . . .	32.90	27.86	32.28	39.42	43.79	41.08
Magnesia, carbonic acid, &c.	6.41	5.22	6.08	6.87	7.01	5.51
Silicious matter . . .	3.66	.75	1.60	1.15	.75	1.05
	100.00	100.00	100.00	100.00	100.00	100.00
*Containing nitrogen . . .	3.72	5.33	3.94	1.26	.84	.85
Equal to ammonia . . .	4.52	6.47	4.78	1.53	1.02	1.03
**Equal to phosphate of lime . . .	53.33	46.48	52.83	62.48	72.33	67.72

A.—A high quality of ordinary bone lightly boiled.

B.—Made from horse bones—rich in nitrogen.

Analyses similar to the above are very general in trade circulars.

Dissolving Bones.—About the year 1840 a new departure was made in the manufacture of bones as manure. The development of this trade was rapid and extensive, but farmers became at last alive to the fact that the division of bones could not be carried to such a point as to suit the requirements of the

turnip crop. Mechanical means had been tried, and had not, to the full extent, fulfilled the purpose.

But when Liebig announced that "the most easy and practical method of effecting their division is to pour over the bones, in a fine powder, half their weight of sulphuric acid diluted with three or four parts of water, and after they have been digested for some time,

to add about 100 parts of water, and to sprinkle this acid-mixture (phosphate of lime) before the plough," it was thought a solution to the problem had been found.

The plan could hardly be said to have come into use, as it was open to much objection on account of the form in which the bones were to be applied to the soil. A dressing of 1 cwt. of the dissolved mixture, entailing the application of nearly a ton of water, was simply impracticable in most cases of ordinary farming. A remedy was found in putting less acid in the mixture, and thereby producing a nearly dry product which could be sown by hand or machine. This substance came quickly into favour with all classes of farmers, as they found the manure to be easy of application, rapid in its action, and in most climates and soils never failed to produce an increase of crops.

The late Dr Aitken did not approve of dissolving bones. He wrote: "Considering the enormous quantity of mineral superphosphates now available, I am strongly of opinion that it is a mistake to dissolve bones, and that they are put to a much better use by applying them in their natural state in as finely ground a condition as they can possibly be got. The germ-life in the soil and in the bones will very rapidly convert the whole into a form available for the nourishment of plants; but to dissolve bones in sulphuric acid is to kill out the germ-life within them, and retard the decay of any nucleus of bone the manure may contain."

Dissolved Bones and "Dissolved Bone Compounds."—Formerly the name "dissolved bones" was applied to all sorts of mixtures of which bone formed part. Now, however, since the passing of the Fertilisers and Feeding Stuffs Act, the name "dissolved bones" is restricted to manures made from bone and acid only. Mixtures made from bone and acid with mineral phosphates and nitrogenous matters other than bone are now called "dissolved bone compounds."

Pure vitriolised bones generally contain from 30 to 35 per cent of phosphate—of which half to two-thirds is soluble in water—and nitrogen equivalent to about 3 to 3½ per cent of ammonia.

The advocates of the use of pure dissolved bones lay stress on the intimacy of combination between the nitrogenous matter and the phosphate, and especially on light soils. There are numerous farmers who stoutly maintain their preference for this form of manure over applications of superphosphate merely mixed with nitrogenous manure, such as sulphate of ammonia.

Dissolved bone compounds occupy a somewhat intermediate position. Their nitrogen is sometimes derived from bone, sometimes also from dried blood, fish guano, or shoddy. If these materials are well dissolved by the acid they will blend very closely with the phosphates. Unless the insoluble phosphate in these "compounds" is mainly in the form of bone, it has little value.

Dissolved bone compounds vary in percentages of phosphates or nitrogen: 18 to 22 per cent of soluble phosphate, 8 to 12 per cent of insoluble phosphate, and about 1.2 per cent of nitrogen, equal to 1.5 per cent of ammonia, are common limits guaranteed by vendors.

The farmer can make a good dissolved bone compound for himself by intimately mixing ordinary superphosphate with bone-meal, two parts of the former to one of the latter, if he wants a quickly acting mixture, or equal parts if he has a sandy soil or a soil poor in lime, on which it is undesirable to use a very acid manure. The bone-meal will neutralise the acidity of the superphosphate, and turn the soluble into "precipitated" phosphate—a very useful form of manure.

Probably, for most purposes, the use of superphosphate with suitable nitrogenous additions is more economical than that of purchased dissolved bone compounds; but the relative cost must be carefully studied in any particular case, and also the cost of labour in home mixing. The cheapest and most abundant form of soluble phosphate, at any rate, is mineral superphosphate.

Mineral phosphate, when dissolved, is as efficient a plant-food as phosphate obtained from bones. When once brought into a soluble condition the only difference which exists between the forms—bone and mineral phosphates—is the presence of nitrogen in the bones.

Coprolites.

Origin of the Manure-trade.—It has been shown that a new era began in the agriculture of this country with the introduction of bones as a manure. As the results obtained became known and appreciated, increased attention was given to the question of manuring, and active research was made for other fertilisers.

Fresh substances were found, and proved to be successful and economical as fertilisers. A large increase in the demand for these manures rapidly arose, and with this movement began the manure-trade of this country. To give an idea of the dimensions to which it has now grown, we may quote the following figures, taken from the evidence given by Mr Hermann Voss (of the Anglo-Continental Guano Works) in the year 1904, before a Committee of the Board of Agriculture appointed to inquire into the working of the first Fertilisers and Feeding Stuffs Act. Mr Voss estimated the annual home consumption of artificial and imported fertilisers as follows:—

	Tons.
Nitrate of soda	75,000
Sulphate of ammonia	25,000
Bone-meal	40,000
Basic slag	150,000
Potash salts	75,000
Guano	30,000
Other "raw" manures (such as fish guano and various other organic manures)	50,000
Superphosphate, dissolved bones, dissolved bone compounds, and other manufactured fertilisers	850,000
Total	1,295,000

It may be added that the world's consumption of superphosphate is estimated at something like 6,000,000 tons per annum.

Cambridge Road-scrappings.—In the rise and progress of this trade the effect of any substance when used as a manure was closely observed, and we can therefore understand how the road-scrappings of Cambridge came into notice. These scrapings, on being examined, were found to be in part composed of phosphate of lime, obtained from phosphatic nodules, which were dug up out of the underlying "greensand," and used for repairing roads. Dr Buck-

land, their discoverer, found these nodules to be a mineral phosphate, and consequently nearly insoluble. They are now known under the name of *coprolites*.

A considerable period elapsed after the discovery of these nodules before they came to be used as manure. The writings of Henslow and Hérath, who minutely described the extent and composition of this manurial wealth, effected this object by bringing these resources under the notice of the Royal Agricultural Society of England.

Origin of Coprolites.—Coprolites, or dungstones, are the excrements and remains of saurians or lizards, *Ammonites*, *Belemnites*, &c.

Sources of Coprolites.—The digging of coprolites was at first confined to the midland counties, where they were found in the greensands of Cambridge, the green marls, the gault, the bone-beds of the Lias, Ludlow bone-beds, Suffolk Crag, &c. After a time immense deposits of coprolites or analogous minerals were found in various parts of Europe and America. These deposits are of various qualities. Those found in the Suffolk Crag, in Buckingham, &c., were at one time known as false or *pseudo* coprolites, from their containing a considerable quantity of alumina and oxide of iron. It has been suggested by Dr Buckland that the coprolite of this description was at one time chalk, which, after absorbing phosphoric acid from the decay of organic matter, was ultimately altered by natural forces into a mineral phosphate.

Another theory as to the origin of these and other mineral phosphates has also had support. It was supposed that they were at one time nearly the same as many of the phosphatic guano deposits, and had been altered by rains and afterwards by changes in the earth's crust, so as to be converted into the nodules or phosphatic rocks now so largely employed in the manufacture of *superphosphates*.

Dissolving or Grinding.—Formerly chemists were of opinion that mineral phosphates, unless treated with acids, were practically useless as a manure. Modern research, however, has shown that, if ground to an impalpable powder, they are of considerable value as fer-

tilisers, though inferior to superphosphate.

All, however, agree that mineral phosphates, when dissolved, become a safe and valuable source of phosphoric acid for plant-growth.

Composition of Coprolites.—The English beds of coprolites are, for the most part, either exhausted or no longer

pay to work, in view of the abundant other supplies of phosphatic minerals; while those of Carolina are no longer imported in any considerable quantity. Nevertheless, it is of historical interest to record the composition of coprolites of formerly well-known types. The following are average analyses of coprolites by Sibson:—

	Cambridge.	Bedford.	Suffolk.	Carolina.	French.
Moisture . . .	1.24	2.06	1.03	1.04	1.90
Phosphoric acid ¹ . .	26.80	23.52	25.50	25.70	20.80
Lime . . .	43.26	33.46	37.24	37.38	31.94
Carbonic acid . . .	7.10	...	3.60	...	3.80
Other matters . . .	12.70	16.54	20.50	16.76	15.03
Sand . . .	8.90	24.42	12.13	19.12	26.53
	100.00	100.00	100.00	100.00	100.00
¹ Equal to tribasic phosphate of lime	58.50	51.34	55.67	56.10	45.41

The preceding are very similar in composition, and may be taken as fair representatives of the phosphatic nodules.

But there are many other sources of insoluble phosphates. We shall mention briefly a few of those best known.

Apatite, Phosphorite, and Phosphatic Layers.

These substances occur in varied proportions in nearly all rocks, but are more abundantly present in the Metamorphic. They are much alike in character and composition. The existence of these layers, veins, and pockets seems to be due to the decay of organic matter; the residue being mixed up with shells of various kinds in which phosphate of lime is present in considerable abundance—these being deposited during long periods of time, and compressed amongst the other rock-material. Granite and syenite seem to be more largely interspersed with these substances than other rocks, and we have, in consequence, the best corn-

growing lands on soils which overlie these rocks.

Apatite is found largely in Canada and Norway, where it is present in veins and masses. It exists in lesser quantities in other parts of the world.

Phosphatic layers are generally poor in quality, and are met with in the Silurian rocks, notably in Wales. *Phosphorite* is very abundant in some parts of Portugal, but these sources have not as yet been fully developed in consequence of bad roads. It is more sparsely present in Spain and Germany. The Canadian phosphorite beds have not been fully explored. The specimens which have been sent to the market are extremely hard and brittle, very difficult to grind—the powder obtained being minute glassy particles of a crystalline form. This renders it more insoluble than most other phosphatic materials.

These substances are for the most part manufactured into superphosphates.

Composition of Phosphorite.—Undernoted are analyses of average specimens:—

	Canadian Phosphorite.	German.	Spanish.
Moisture . . .	Traces.	1.30	Traces.
Phosphoric acid ¹ . .	35.30	28.02	33.60
Lime . . .	47.22	37.11	42.02
Other constituents . .	11.98	15.44	8.11
Sand, &c. . .	5.50	18.13	16.27
	100.00	100.00	100.00
¹ Equal to phosphate of lime	77.06	61.17	73.35

The following is a list of the chief sources of mineral phosphate now used for conversion into mineral superphosphate:—

Algeria, Belgium, Florida, France, and South Carolina. The exports from Canada, Spain, and Norway have for the present been stopped by the less

cost attaching to the mining and shipping of material from the other countries enumerated. The following are typical analyses of phosphates from Algeria, Belgium, and Florida (rock and pebble), and serve to indicate the composition of the materials from which superphosphate is now (1906) chiefly made in England:—

Analyses of Commercial Phosphates largely used for Superphosphate Manufacture.

	Florida Rock.	Florida Pebble.	Algerian ("55 to 60").	Algerian ("60 to 65").	Belgian.
Phosphoric acid ¹	35.79	32.46	26.75	29.10	19.98
Lime	50.17	46.28	51.21	49.39	49.51
Alumina	1.51	1.37	.36	.44	.53
Oxide of iron	.75	1.40	.20	.25	.60
Carbonic acid, fluorine, &c.	7.42	10.14	19.38	19.42	25.43
Silicious matter	4.36	8.35	2.10	1.40	3.95
	100.00	100.00	100.00	100.00	100.00
¹ Equal to phosphate of lime	78.12	70.86	58.39	63.52	43.62

Sombrero or Rock Guano.

This substance is found in the West Indian island of Sombrero, hence its name. There can be little doubt that the greater part of the islands in the Caribbean Sea were at one time covered with guano deposits in the same manner as those found on the islands of the South American and African coasts. These and similar deposits, by natural agencies, have been converted into the phosphatic rock which covers the greater part of this and the other islands of the West Indies. This rock has become known in the manure-trade as Sombrero Guano, and was once largely used in the manufacture of compounds and other soluble phosphatic manures.

"Redonda" and "Alta Vela" Phosphates.

The preceding are all phosphates in which the phosphoric acid is in combination with lime as a base. In Redonda phosphate we have instead of lime a base composed of alumina and iron. This substance can be applied to the soil in its natural state only in a finely divided condition, as the absence of lime in its composition prevents the treatment of it with acid. Its efficiency is considerably increased by calcination; but in view of the abundant supply of basic slag, which is more useful, it has been little employed.

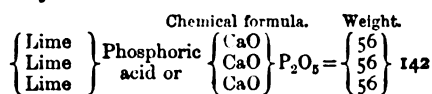
Basic or "Thomas" Slag.

We have in this substance a cheap and abundant source of phosphoric acid. It has been in the market only since 1886. The results of a very large experience wherever phosphatic manure is needed clearly show that this substance is an excellent source of phosphoric acid for plants. It is, indeed, more quickly available to plants than any previously known form of insoluble phosphate. As it is now produced in Europe to the extent of about 600,000 tons per annum, the discovery of its manurial value has been of great importance to agriculture. It is estimated that something like 150,000 tons per annum are now (1907) used for manure in the United Kingdom alone.

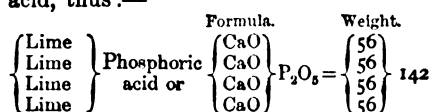
Source of Basic Slag.—Basic slag is a by-product obtained in the conversion of pig-iron into steel. Formerly all the slag resulting from the Bessemer method was a waste product, and it often became a serious difficulty with manufacturers how to get rid of it. It was therefore allowed to accumulate in those unsightly heaps which are always seen in connection with iron factories. In the original Bessemer process the crucibles or "converters" in which the pig-iron was burnt into steel were lined with silica bricks. The process only allowed the best pig-iron to be utilised for steel, as the objectionable phosphorus of low-

grade pig-iron was not removed in the process. The process now in universal use was patented in 1879 by the inventors, Thomas & Gilchrist. The method consists essentially in lining the converter with lime instead of brick. The various impurities, such as manganese, silicon, phosphorus, and carbon, combine with the oxygen present in a stream of air which is forced through the molten mass, forming oxides with these substances. The phosphorus of the crude iron is converted into phosphoric acid, which combines with the lime, and the resultant product is the now familiar basic slag. The possible utility of the slag for manurial purposes, however, was for a long time unsuspected. The process enabled vast quantities of low-grade iron ore to be made into good steel, but the value of the mere by-product was not anticipated. Experiment, however, eventually disclosed the fact that when ground very finely it made an excellent phosphatic manure, despite its insolubility in water, being in this respect widely different from finely ground natural mineral phosphates. All that is necessary to prepare it for manure is to grind it finely, which is usually done in centrifugal disintegrators, removing the particles of iron by means of magnets. Its much more rapid availability as plant food, compared with ordinary mineral phosphate, arises from its peculiar composition.

In bones and mineral phosphates we have three molecules of lime as a base combining with one molecule of phosphoric acid to form the salt termed phosphate of lime. The combination may be stated thus:—



Now, Thomas slag has four molecules of lime in its composition, in combination with one molecule of phosphoric acid, thus:—



If the chemical molecules are translated into proportions by actual weight,

this is equivalent to saying that 168 parts of lime are combined with 142 parts of phosphoric acid in the one instance, and 224 parts of lime with 142 parts of phosphoric acid in the other. That is to say, in Thomas slag the acid is combined with what we may call too great a proportion of lime to enable it to cohere permanently in a staple form. To put it in another way, its chemical affinity is weakened from being over-saturated with lime, so that the compound is more readily broken up. Hence when the slag is exposed to air in the soil, the carbonic acid of the air and of the soil seizes on the fourth molecule of lime, with the result that the minute more or less crystalline particles composing the slag break up into still more minute fragments of tribasic phosphate, the very finely divided state of which renders them easily soluble in the natural solvents of plant food.

Oxide of Iron in Slag.—The oxide of iron in slag appears to exercise no deleterious effect on the growth of crops.

Composition of Slag.—Slag also contains, beside phosphate and silicate of lime, a considerable quantity of caustic or free lime and magnesia. The following is an average analysis of Thomas slag:—

Phosphoric acid . . .	18 per cent
Lime	50 "
Oxides of iron, &c. . .	22 "
Silica	7 "
Magnesia	3 "

The quantity of phosphoric acid in a sample depends, however, on the amount of phosphorus present in the iron, and the quantity of lime which is added to the molten liquid. If an excessive quantity of lime be added, then the residue may be poor in phosphoric acid, and *vice versa*. The phosphoric acid in basic slag is commercially calculated into the form of tribasic phosphate of lime (ordinary "bone phosphate"). The proportion of phosphate in basic slag may vary from as little as about 20 per cent up to as much as 50 per cent. The quantity has to be guaranteed by the vendor within close limits.

The mere total percentage of phosphate is not a sufficient guarantee, however, of the utility of the slag. Its

efficiency as a manure is very largely dependent on its fine grinding, and it is usual to guarantee that at least a certain percentage (80, or 85, or 90) will pass through a sieve of fine wire-gauze having about 10,000 meshes in a square inch, known as No. 100 E, made by Amandus Kahl of Hamburg. It is also usual now to guarantee that at least eight-tenths of the total phosphate shall dissolve in a solution of citric acid applied as directed by the Board of Agriculture. This is to prevent adulteration with ground mineral phosphates.

The caustic lime in slag, although a good manure, prevents slag forming an all-round ingredient in mixing manure, as in this form it is a strong alkaline base, which will readily drive out a volatile one, as ammonia. If these be mixed, the lime combines with the sulphuric acid, and the ammonia escapes into the atmosphere.

Further information on this point will be found under "Mixtures and Mixing," p. 508.

Basic slag is a good all-round phosphatic manure, being especially valuable on soils poor in lime. It has a most beneficial action on poor grass-land, especially encouraging the growth of clovers.

Soluble Phosphates or Superphosphates.

When Sir John Bennet Lawes, about the year 1840, announced that he could obtain *soluble phosphate of lime* from the mineral phosphatic nodules as represented by *coprolites*, it is not to be supposed that he then realised that from this discovery a special industry would develop, which would go on increasing to the enormous volume it has now reached. The great value of this discovery to the agricultural world becomes apparent by a consideration of the large and increasing quantities of superphosphate which farmers require under the changes which the application of artificial manures has effected in the rotation of crops, and the ever-diminishing supply of phosphates. It is estimated, as has been already said, that the quantity of superphosphate and dissolved bone manures now used by the farmers of the United Kingdom amounts to 850,000 tons per annum, while the world's total

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manufacture of superphosphate and kindred "dissolved" manures is probably 6,000,000 tons annually!

Composition of Phosphate of Lime.

—In order to understand the nature of superphosphate we must understand something of the chemistry of phosphate of lime. Phosphoric acid and lime in combination are the ingredients in the salt, phosphate of lime. These substances are present always in the same proportion in bone phosphate and most mineral phosphatic materials—with the one exception of slag. This combination is known as insoluble, tribasic, or tricalcic phosphate, which consists of three atoms of lime and one atom of phosphoric acid, thus—

	Formula.	Weight.
$\left\{ \begin{array}{l} \text{Lime} \\ \text{Lime} \\ \text{Lime} \end{array} \right\}$	Phosphoric acid or $\left\{ \begin{array}{l} \text{CaO} \\ \text{CaO} \\ \text{CaO} \end{array} \right\} \text{P}_2\text{O}_5$	$\left\{ \begin{array}{l} 56 \\ 56 \\ 56 \end{array} \right\} 142$

Solubility of Phosphate of Lime.

—In this form phosphate of lime is very slowly soluble. Were it not that this substance when applied to the soil comes into contact with water impregnated with carbonic and other acids, the phosphate would remain unaltered for years. But the carbonic acid and water possess considerable dissolving power, and when insoluble phosphate is acted upon by carbonic acid, a molecule of lime is taken away and water takes its place, so that the phosphate is now changed into a more soluble form.

Precipitated, Reverted, Dicalcic, or Reduced Phosphates.—This form is also effected by mixing superphosphate with bones, slag, or caustic lime, before applying it to the soil. Superphosphate also assumes this form after being applied, as the phosphoric acid rendered soluble will then combine with any free base which may be present in a fertile soil. Reverted phosphate may be represented thus—

	Formula.	Weight.
$\left\{ \begin{array}{l} \text{Lime} \\ \text{Lime} \\ \text{Water} \end{array} \right\}$	Phosphoric acid or $\left\{ \begin{array}{l} \text{CaO} \\ \text{CaO} \\ \text{H}_2\text{O} \end{array} \right\} \text{P}_2\text{O}_5$	$\left\{ \begin{array}{l} 56 \\ 56 \\ 18 \end{array} \right\} 142$

Manufacture of Superphosphate.

We have next to consider the artificial method of rendering insoluble phosphates soluble. The raw material is first ground into a fine powder, after which it is placed in a vessel termed a mixer and treated

2 K

with sulphuric acid. It depends upon the composition of the raw material and the strength of the acid as to the exact proportions in which these substances are mixed, more acid or less being employed in proportion to the carbonate of lime present. The general rule is to give as much acid as the material will take up quickly and dry readily after. In practice the quantity of acid varies from one-third to the full weight of the phosphatic material.

The value of a superphosphate depends on the amount of soluble phosphates present. It is therefore questionable policy to stint acid—at least, from a manufacturer's point of view,—as the unit value of soluble is much greater than that of insoluble phosphates. When the acid is put into the mixer, chemical action at once begins by the sulphuric acid, which is strong, driving out the weaker carbonic acid. It then attacks the phosphoric acid combination, and abstracts two atoms of lime from it, the vacancy being made up with water. After a short time the bottom of the mixer is opened, and the whole mass drops into an inclosure known as the den. In a day or two the mixture sets or dries quickly; it is then passed through a disintegrator, bagged up, and sold under the name of "superphosphate."

This product, on examination, is found to have undergone a change different from the other forms, as the compound now retains only one atom of lime in combination with the phosphoric acid, and may be stated thus—

		Formula.	Weight.	
{ Lime Water Water }	Phosphoric acid or	{ CaO }	P_2O_5 { 56 18 18 }	142
		{ H ₂ O }		
		{ H ₂ O }		

In chemical parlance this substance is designated monocalcic tetra-hydric phosphate, but it is usual in analysis not to state the quantity of this substance, but the quantity of tricalcic phosphate from which it was made—that is, the tribasic or tricalcic phosphate of lime rendered soluble by the acid. In this form it is in its most soluble condition, as it can be held in solution by water.

When the superphosphate is distributed in the soil it combines with lime or other soil bases forming "reverted" phosphate—no longer soluble in mere water,

but available as plant food. When this change is effected, it becomes a precipitate, and is then in the most finely divided condition a substance can assume. Many farmers consider the reverted form the best form in which to apply phosphate of lime, holding that it is more quickly effective upon crops, and that the superphosphate form is over-soluble, and liable to escape into the subsoil or drains if a base is not present. Hence the mixing of superphosphate with bone dust, or with lime itself (as in the case of the "basic" superphosphate patented by Mr Hughes). Doubtless, on soils in which carbonate of lime is absent the too frequent use of acid manures in their raw state appears to be undesirable.

But there are advantages which arise from the use of acid or soluble phosphates, as in superphosphate—viz., the greater power of diffusion a substance has when it is held in solution by water; because this water, which is impregnated with phosphoric acid, first distributes the phosphoric acid freely in the soil. After distribution it is precipitated by lime or other soil bases; but the precipitated phosphate thus produced is dispersed throughout the soil in a way which could never be attained by any mechanical means.

Bone or Mineral Phosphate.—It is held by eminent chemists that the soluble phosphates obtained from mineral phosphates are equally good as those from bones, and that there is no special virtue in one form over the other. It is therefore of little importance to the farmer from which source his soluble phosphates are made, provided the material is fully dissolved, and in a dry, powdery condition.

But from this we do not infer that superphosphates are as good a manure as dissolved bones. We merely conclude that the soluble phosphates present in each are equal in value as fertilisers. The dissolved bone owes its greater efficacy to the nitrogen; but then this nitrogen can be supplied to the superphosphate either as bone-meal or sulphate of ammonia, by which means we can secure a cheaper manure, with an equal if not a greater amount of fertilising matter.

Composition of Superphosphates.—Superphosphates vary in composition according to the mixture and composi-

tion of the phosphates from which they are made and the skill of the manufacturer. Formerly the most usual percentage of soluble phosphates was about 26. Now a large quantity of 35 per cent phosphate is made, and higher grades are made for export purposes to save freight. In any case, the percentage is necessarily declared by the makers, and the farmers can tell by comparing prices and guarantees of different makes which is cheapest to buy. Mechanical condition is of the greatest importance. Superphosphates should be friable, "dry," and free from large lumps. If moist or lumpy it clogs the drills and distributors, and causes uneven sowing.

The percentage of soluble phosphates which average samples contain is shown below :—

	High-class Superphosphate.	Medium Superphosphate.	Low-class Superphosphate.
Soluble phosphate (per cent).	35 or more	28 to 30	23 to 26

Choice of Phosphatic Manures.

In the selection of the form in which to apply phosphate to his crop, the farmer has to consider the character of the soil, climate, and crops to be grown. The remarks made upon nitrogenous manures apply with equal force to all kinds of phosphates.

It may be laid down as a general rule that soluble or acid manures, like superphosphate or dissolved bone, are the most economical as well as most rapidly efficacious forms of phosphate to use on all soils containing enough carbonate of lime to effervesce freely when mixed with hydrochloric acid. On soils, on the other hand, very poor in lime, acid manures should only be used occasionally, or after liming. They may be used, perhaps, in alternate years with dressings of basic slag in between; but not year after year, unless lime is applied. On acid soils (such as some forms of peaty soil) we should use as a source of phosphate either basic slag, guano, or fine bone-meal. Or if superphosphate is used, it should be superphosphate neutralised by mixing it with lime ("basic superphosphate") or with bone-meal.

Dissolved manures are no doubt the most active. The chief advantage of

this solubility is their certainty of action, the rapid manner in which they become available in any soil or climate. The young plant is in consequence supplied with this essential ingredient at a period of growth when it is liable to sustain damage from untoward influences which may infest its surroundings. An abundant supply of manure or food at this critical period to a great extent determines the future crop, an increased yield of well-filled grain and early maturity being the results.

Large crops require large doses of manure, and short-lived crops require quick-acting manures. A crop such as wheat, which occupies the ground for a long period, will not be benefited to the same degree by a ready supply of phosphates as a short-lived crop like barley. Wheat abstracts the ingredients at leisure, and can search for them over a much larger area of the soil. And as phosphates are present in some proportion in all soils, this crop can, as a rule, acquire all its wants during the period of growth. Barley, on the other hand, grows rapidly, building up its tissue in a comparatively short time, and, owing to its root-surface, has not the area nor the time to search for its supply of phosphates.

In the well-known work, *How Crops Grow*, we are told that the phosphorised oils require phosphates for their elaboration; that phosphates increase the diffusive rate of albumen, and thus help its transference to the different parts of the plant; and that phosphates co-operate with the other ash ingredients in building up the proximate constituents, such as starch, dextrine, &c., and is ultimately deposited in the seed. We are also aware that a deficient supply of phosphates produces light grain and diminished yield. Phosphates produce dense roots, of excellent feeding quality and high keeping properties.

POTASSIC MANURES.

The use of potash manures is of comparatively recent date. Even yet many farmers do not consider the application of potash to the soil necessary. Its utility depends, no doubt, largely on the nature of the soil, and also on the system of farming adopted.

Sources of Potash.—The only available sources of potash, before 1860, were wood-ashes, sea-weed, and farmyard manure. In 1859 vast deposits of potash salts were found by the Prussian Government when sinking a shaft at Stassfurt in the hope of discovering rock-salt. Overlying large deposits of rock-salt, they found layers of crude potash salts, and magnesia salts of various types—some being approximately pure salts, like muriate of potash (potassium chloride), or magnesium sulphate; others being mixtures of the sulphates and chlorides of potassium, magnesium, and sodium. Similar deposits were also found at Leopoldshall, in Anhalt.

The discovery of these deposits put the use of potash as a manure within the reach of the farmer. "Kainit" can be now bought for about £2 a ton, containing about 12 per cent of potash (or about 23 per cent of sulphate of potash); or sulphate of potash of 90 per cent purity or upwards can be got for about £10 a ton, or muriate at somewhat less.

Use of Potash.—But notwithstanding its low price, potash has not come into general use. As a rule, it can be applied with advantage in ordinary farming only to certain crops, and on land deficient in clay, such as sandy or peaty soils.

When farmyard manure is applied, a separate dose of potash is for most crops unnecessary. Indeed it would be liable to lessen the produce, and also lower its quality, as with the potash in the dung there would be more available potash in the soil than would be beneficial for the crop. On most soils containing a fair proportion of clay, and where a good deal of farmyard manure is used, there is, as a rule, a sufficiency of potash. Sometimes, however, even clay soils are far poorer in potash than might be expected. But where it is deficient, the gain in produce obtained by a small application of potash, at a cost of a few shillings per acre, is often remarkable. By observation and experiment with light doses on plots, farmers may ascertain if their soil needs potash, and if so, its application in moderate quantity will be sure to be profitable. Potash has been found on certain soils of some benefit when applied to mangels, especially in absence of dung, and appears to be of considerable

benefit when mixed with other manures and applied as a top-dressing for hay and clover seeds. It also may be applied with advantage to leguminous crops, beans in particular. Indeed potash is the dominant ingredient of manure for beans in almost all soils. Potatoes are especially grateful for potash, and on moist soils 1 cwt. of sulphate of potash will be found beneficial even with a fair dressing of dung.

Onions, carrots, parsnips, and beetroot are very imperious in their demand for a readily available supply of potash, while plants of the cabbage kind seem to possess greater natural facilities for getting potash out of the natural supplies of the soil. Wherever applied, potash salts ought to be sown early.

GYPSUM.

Sources of Gypsum.—Gypsum, or sulphate of lime, occurs as rocks in the form of beds, generally in conjunction with rock-salt. In the compact form it is commonly known as alabaster and selenite. Many of the deposits owe their origin to the evaporation of salt water, which contains gypsum in solution. At one period, where rock-salt is now found, there must have been inland lakes or seas, and by changes of the earth's surface the outlets have been gradually cut off from the sea; so that all the saline matter brought down by the drainage has been accumulating, the water becoming more and more impregnated with these salts, and thus, when evaporation has gone on for a certain period, the salts cannot be longer held in solution, and, becoming crystallised, they are deposited in the form of beds, which by compression assume the compact form.

Use of Gypsum.—From an agricultural point of view, gypsum is valuable chiefly as an absorber of ammonia (p. 485). It is of benefit to clover and other leguminous crops.

The value of gypsum as a manure was the subject of much discussion about 1850 to 1860; but since the introduction of dissolved phosphates it has been unnecessary for the farmer to trouble himself about it, as the application of 5 tons of superphosphate involves an application of 2 tons of gypsum.

GAS-LIME.

In the manufacture of gas, many impurities have to be got rid of before the gas is ready for combustion. Amongst these are gas-liquor, from which sulphate of ammonia is obtained, and gas-lime, which is produced by spreading quick or caustic lime over plates in a close chamber, through which the gas containing sulphuretted hydrogen is forced. This latter substance combines with the lime, forming in the purifying chamber sulphide of lime. In this form it is destructive to vegetable life; but after exposure to the atmosphere it absorbs oxygen, and is thereby changed into *sulphate of lime or gypsum*. Any caustic lime which may be present is also changed into carbonate.

Use of Gas-lime.—Gas-lime ought to be applied in autumn, or allowed to lie some months before using, so as to allow time for the changes just explained to take place. It is unsafe to apply it to any growing crop.

Many Berwickshire and Roxburgh farmers mix gas-lime and salt, and apply the mixture to their leas which are to be broken up for oats. They consider this application to be of service to the corn crops, and a preventive of anbury or finger-and-toe in the green crop. Gas-lime is also much used as an insecticide.

The farmer must be cautioned that gas-lime is not an efficient substitute for quick-lime in reclaiming moss land, opening up stiff clay, or destroying the "finger-and-toe" fungus. Gas-lime supplies the element calcium, and as some of this is in the form of carbonate, it

increases the alkalinity of the soil, and aids nitrification.

COMPOUND MANURES.

In addition to the various manures already enumerated, there are in the market many *compound manures* or special crop mixtures bearing different names, such as cereal, turnip, potato, bean, and grass manures.

Disadvantage of Compound Manures.—Many of these mixtures are skilfully made up, and, when manufactured by respectable firms, analyse well, and give good results on soils for which they are adapted. But there is one great drawback to this system of preparing manures, and it is this, that with such variation in soil, climate, and customs of farming, it is impossible to compound one manure equally suitable for all farms, even in one district. Moreover, the trade in compound manures opens a wide field for the unscrupulous dealer who would sell inferior stuff as good material. Upon the whole, therefore, it is safer for the intelligent farmer to avoid mixed manures and select fertilisers from sources as to which there can be no suspicion, and blend these in mixtures suitable for the soil and climate where they are to be applied.

Still there are many farmers who are not sufficiently acquainted with the characteristics of the various manures to enable them to ensure perfect mixing, and in these cases it will be advantageous to have the mixtures prepared by a thoroughly respectable firm, by whom the composition of the mixture will be guaranteed.

PURCHASING, MIXING, AND APPLYING MANURES.

PURCHASING OF MANURES.

There are a few points in connection with the purchasing of manures which farmers should always keep in view. From simple examination of any article sold as manure, the purchaser can have little or no idea of its quality or value as

a fertiliser. For this reason the farmer ought—

- (1) To buy only from respectable firms.
- (2) Never buy without obtaining a guaranteed analysis.
- (3) Always buy the valuable ingredients from the cheapest sources in the market.

The first point is so self-evident as to require no further remarks.

Fertilisers and Feeding Stuffs Act.

The purchaser of manures is specially protected by the Fertilisers and Feeding Stuffs Act. This Act provides that every seller of an artificial manure shall give with it an invoice stating the name of the manure and what are the percentages, if any, of nitrogen, soluble phosphates, insoluble phosphates, and potash contained in it. The invoice has the effect of a warranty to the seller that the actual percentages do not differ from those stated except within small limits of error fixed by the Board of Agriculture. The purchasers of fertilisers are thus specially protected, for the sellers must give them in the invoice a guarantee of the valuable constituents—nitrogen, phosphates, soluble and insoluble, and potash—of the manure.

If, then, the purchaser of a manure understands the terms used in the analysis in the invoice, he should be able to judge approximately whether the manure guaranteed is a good one or not.

Insoluble and Soluble Phosphates.

—As to the meaning of the terms insoluble phosphate and soluble phosphate some explanation has already been given in the notes upon superphosphate, p. 501. It was there seen that *soluble phosphates* always means *tribasic phosphate of lime made soluble by an acid*.

The soluble phosphate in ordinary manures is phosphate soluble in water. But in the case of basic slag which contains no phosphate soluble in water, it is now usual to give a guarantee of phosphate *soluble in citric acid* of a prescribed strength. This custom has been recognised by the Act. Citric acid is a weak acid, and phosphate, soluble in it though not soluble in water, is fairly available for plants. Three classes of phosphates are therefore now recognised—phosphates soluble in water, phosphates soluble in citric acid, and phosphates not soluble in either of these. All these classes of phosphates are calculated to tribasic phosphate of lime, no matter whether they exist in the manure in that form or not.

Nitrogen and Ammonia.—Nitrogen is found in manures in three forms—(1)

as nitrates, (2) as ammonium compounds, and (3) as organic compounds of nitrogen. It was formerly customary to express nitrogen in terms of ammonia, and this is still often done. The term used in the Fertilisers and Feeding Stuffs Act, however, is nitrogen, and it is now customary to guarantee the percentage of nitrogen as nitrogen in accordance with the Act, though it is also usual to add the equivalent percentage of ammonia. Thus we have such a statement as that a manure contains 7 per cent of nitrogen, equal to $8\frac{1}{2}$ per cent of ammonia. It is to be remembered that these are not separate guarantees but different methods of stating the same thing. The ratio between nitrogen and ammonia is such that 14 parts of nitrogen equals 17 of ammonia, or 1 part of nitrogen equals 1.214 parts of ammonia.

Nitrogen is in its most active and available forms, and therefore in its most valuable forms, in nitrates and ammonium compounds. In organic compounds we have nitrogen of various degrees of activity as manure. The chief organic substances which are used in preparing artificial manures are guano, blood, meat, fish, bone, skin, wool, horn, hoof, and leather. The nitrogen of guano, blood, meat, and fish is comparatively quickly available, as these substances rot readily in the soil and liberate their nitrogen in forms suitable for the use of plants. Bone, skin, wool, horn, and such substances, act more slowly and are therefore of less value, while leather is the slowest acting substance of all, and is of little value unless specially prepared by treatment with acid.

Potash.—Potash is used as manure almost entirely in the form of soluble salts, such as kainit, potash manure salt, muriate of potash, and sulphate of potash. In all of these the potash is present either as the sulphate or as the chloride.

Lime.—The above are the most important constituents of manures, but another constituent of considerable importance is lime. Lime in the form of phosphate, sulphate, carbonate, or silicate, is present in many manures, but its percentage is not usually stated. In the case of manures, such as lime-shells and ground-lime, which are bought for their alkaline or caustic lime—that is,

for their free lime or calcium oxide—a guarantee of the percentage of caustic lime present should be obtained. A good sample of ground-lime should contain at least 70 per cent of caustic lime. Lime-shells contain from 70 to over 90 per cent of caustic lime.

Minor Constituents.—Minor constituents, the percentages of which are sometimes stated in the analyses of manures, are the *moisture* or *water*, the *organic matter* or combustible matter, and the *sand* or *insoluble silicious matter*. A statement of the sand or insoluble silicious matter is often valuable, as, for instance, in the case of bones, in showing whether the manure is pure and clean.

The Cheapest Source.

The greatest difficulty the farmer has to encounter when purchasing manure is to know the best sources from which to obtain phosphoric acid, nitrogen, and potash. In order to enable him to form an approximate opinion of relative values, we shall try to explain the theory of valuation by units, precluding it with the remark that the *value of a manure to the farmer* depends on the amount of valuable ingredients which may be pre-

sent in its composition, but that its *market price*, like that of all other commodities, is regulated by the law of supply and demand.

Valuable Ingredients of Manure.—

The valuable constituents in manure are: (1) nitrogen; (2) the phosphate soluble in water, as in superphosphate, or the phosphate soluble in citric acid, as in basic slag; (3) the phosphate insoluble in water, as in bones; and (4) potash, as in kainit.

Nitrogen, phosphoric acid, and potash are available from many other sources, and the degree of availability, and the value to the farmer, vary with the source and nature of the manure. What the farmer has to carefully consider is the form in which these are present, whether *quickly* or *slowly* available, and then judge which will be most suitable for his purpose.

Unit Value.—Let us now see how the unit value is arrived at. The unit is 1 per cent in a ton. Taking the prices per ton stated below as the selling price of the manures, and dividing the price by the number of units of the various useful ingredients—that is, by the percentages of these ingredients,—we find the value per unit of these ingredients would be as follows:—

			Per ton.		Per unit.
Sulphate of ammonia	= 20 per cent nitrogen,	at . . .	£12 5 0	=	£0 12 3
Nitrate of soda	= 15.5 " " at . . .		11 5 0	=	0 14 6
Slag	= 30 " " at . . .		1 15 0	=	0 1 2
Superphosphate	= 26 " soluble phosphates,	at . . .	2 13 0	=	0 2 0½
"	= 38 " " at . . .		3 16 0	=	0 2 0
Muriate of potash	= 50 " potash, at . . .		8 15 0	=	0 3 6
Potash manure salt	= 30 " " at . . .		4 15 0	=	0 3 2
Bones	= { 50 " phosphates, } at . . .		5 15 0	=	{ 0 1 4
	= { 4 " nitrogen, } at . . .			=	{ 0 12 1
Kainit	= 12.5 " potash, at . . .		2 5 0	=	0 3 7

The only difficulty is in regard to a compound manure such as bones. In such a case the unit value of the constituents is obtained by a process of comparison with other manures containing constituents of similar nature and availability, and by noting how the market price varies with the variations in the constituents in question.

The foregoing, of course, cannot be taken as hard-and-fast rules. The chemist or other person making a valuation of a manure by the unit system generally exercises a certain amount of discretion, and takes into account the condition of

the manure, its fineness of grinding, and any other matters which might affect its value. Thus, a finely ground bone-meal costs more to produce than a coarsely ground one, and is also more valuable to the farmer. Fineness of grinding, therefore, is an element to be considered as well as the percentages of nitrogen and phosphates in valuing bone-meals. The foregoing figures will, however, give a useful idea of the approximate value, and indicate how, from the cost price and analysis, the value per unit is arrived at.

Tables of Unit Values.—Tables of unit values of manures are now published

from year to year by several bodies. In particular, the Highland and Agricultural Society of Scotland has for many years past annually prepared such a table at the beginning of the manure season. This table, which is published in the Transactions of the Society, and also issued as a separate leaflet, is based on information given by a number of

leading dealers and purchasers, representing all the chief manure-distributing centres in Scotland.

Estimating the Value of a Manure.—Now, let us reverse the process, and from these values per unit and the analysis of a manure, find what the cost price per ton should be. Take, say, *bone-meal*, showing on analysis—

48 per cent insoluble phosphate, worth 1s. 4d. per unit.	
3¼ " " nitrogen, worth 12s. 1d. "	
The total cost per ton should be £5, 9s. 4d.	

MIXTURES AND MIXING.

Dangers of Careless Mixing.—To enable a farmer to mix his manures without incurring loss of valuable ingredients, it is essential that he must have a knowledge of their character and composition. Indiscriminate or careless mixing is almost certain to end in loss of fertilising material, and may even, by generation of poisonous gases in a close compartment, cause danger to human life.

It should therefore be kept in view that while the substances used as manure are more or less in the form of salts, which are harmless in themselves, yet if their complex forms are broken up, the products of the decomposition assume a very different character.

Chemical Processes in Mixing Manures.—The chemical processes which take place in this decomposition need not be fully described here. For all practical purposes, the substances which result may be regarded as acids in chemical combination with alkalies as bases. In chemical action, a strong free acid will drive out a weak one, and a strong alkali will usurp the place of one possessing a less degree of affinity for acids. If we examine our manure-lists, we find that in

- (1) Highly soluble phosphates, such as superphosphate, there are present free phosphoric acid and acid salts; in
- (2) Nitrate of soda there is an alkali having a strong affinity for acids; in
- (3) Slag there is a strong alkali in the form of caustic lime; and in
- (4) Sulphate of ammonia there is a volatile alkali, ammonia.

When soluble phosphates are mixed with nitrate of soda, a portion of the phosphoric acid combines with a portion of the soda from the nitrate of soda, and part of the nitric acid, which is the valuable constituent of the manure, may be set free as an orange-coloured gas which is poisonous. If $\frac{1}{3}$ of nitrate of soda and $\frac{2}{3}$ of superphosphates are mixed, and allowed to lie for six weeks or so, it may be found that nearly $\frac{1}{3}$ of the nitric acid has been lost from this cause alone.

Mixtures of superphosphates and nitrate of soda must therefore be prepared with care. A dry superphosphate must be taken, and some such dry substance as rape-dust or steamed bone-flour should be well mixed with it before the nitrate is mixed, if the mixture is to be kept. It is, however, always better to sow the superphosphate and nitrate separately.

Again, if superphosphate and bones or slag are mixed, and allowed to remain for some time, the soluble phosphoric acid will combine with another molecule of lime, and more or less of the soluble phosphate will be reverted or turned insoluble. The reversion of soluble phosphate which takes place is only slight when bones are mixed with superphosphate, but may be very serious when slag is used.

Then if we mix sulphate of ammonia with slag, the caustic lime of the slag will drive out ammonia, which, being volatile, will become dissipated in the atmosphere. This action may result in a serious loss of nitrogen from the mixture.

Comparatively few realise the loss and disappointments which have occurred to the great body of farmers by haphazard mixing of manure. The fact is, there

are very few manurial substances which can be mixed at random, and allowed to lie, without some change occurring in their composition.

Advantages of Sowing each Manure Separately.—An experienced and successful agriculturist states that his method is to mix artificial manures as little as possible. With a wide distributing machine he finds the cost of two or three sowings is little more than the labour of perfect mixing and one sowing; and when each kind of manure is sown separately, the land gets exactly what is desired of each constituent at the best time, while all risk of loss in mixing is averted.

Safe Mixtures.—The following manures may be mixed with impunity: (1) bones with nitrate of soda or sulphate of ammonia; (2) superphosphate and sulphate of ammonia; (3) bones and slag; and (4) slag and nitrate of soda. Potash manures, such as kainit or muriate of potash, can be safely mixed with any of these. But mixtures in which potash manures are mixed with superphosphate should be sown at once, as they are apt to become hard on standing. Organic nitrogen, such as fish guano or Frey Bentos guano (or meat-meal), may be mixed with any other manure without incurring loss.

Method of Mixing.—The following plan of mixing has been adopted with a fair amount of success. As short a time as possible before application, the superphosphates are emptied, and the lumps are broken by striking the lump a smart blow with the back of the shovel. Next, a heap of bones, and another of slag, if these are to be used, are put down, leaving a clear space between. A man is now placed at each heap, and alternate shovelfuls, less or more—the quantity being determined by the relative proportion of materials desired—are thrown into the centre, where a new heap is formed containing the three materials. After this mixture is made, it is turned over several times, care being taken to always shovel the material from the bottom of the heap. The top portions of the material slip down, and thus by shovelling from the bottom a thorough mixing is brought about.

In a day or two the sulphate of am-

monia or nitrate of soda, when such is to be applied, may be added. The mixture is then driven to the field in carts, the mixing process being completed by the material being shovelled from the bottom of the heap into the cart. When the manure is to be sown by hand, equal quantities should be placed in each cart, in order to facilitate even application.

By mixing in this manner, the risk of loss through any excess of sulphuric acid having been added to the superphosphate will be averted, as any free acid will combine with the free lime of the slag, or with the bones if there is no slag in the mixture. A neutral salt is thereby formed and loss prevented. As already indicated, it would be unwise (unless one wished to prepare a "neutral" manure) to allow a mixture of fine steamed bone-flour or slag and superphosphate to lie long, as the phosphates in the superphosphates would be precipitated by the bone-flour, or by the caustic lime in the slag.

Another Method of Mixing.—Another good method of mixing manures for turnips is as follows, the mixing being done in a turnip-shed, about 16 ft. square: A layer of bone-manure is laid down over the whole area, next a layer of superphosphate, next another of bone meal or dust, on which is put a layer of fish guano; then another of the bone-meal, on which is laid a layer of kainit, and the same system gone over a second time till a quantity sufficient for 20 acres is laid down. A layer of the bone-manure is always put between each of the other kinds used, and, as a rule, only a day or two before being required for use. The heap has sometimes lain two weeks without, as far as one could see, sustaining any injury; but it is well to be careful to have a layer of the bone-meal between the other layers, and the heap should not be stirred till it is about to be used.

Mixtures injured by lying long.—If a long time is allowed to elapse before application, then reversion of phosphates will set in; nitric acid or ammonia may be evolved, although in less degree; and the mixture may become damp and lumpy, and form into cake, which will prevent its even distribution.

Early application after mixing is there-

fore usually desirable. On the other hand, for some purposes, as will have been gathered in reading the foregoing pages relating to manures, keeping may enhance the value of the mixture.

Guano, dissolved bones, superphosphate, and sulphate of ammonia ought all to be riddled, and lumps broken before mixing.

Compounding Mixtures and Character of Manures.—In order to enable the farmer to make an approximate calculation of the quantities of the several manures he will require to make up a mixture containing certain proportions of soluble phosphates, insoluble phosphates, nitrogen, and potash, we append the following information:—

Nitrate of Soda.—The most available source of nitrogen; the commercial article contains about 95 per cent pure nitrate, equal to about 15.6 per cent nitrogen.

Sulphate of Ammonia.—A little slower and more prolonged in action; contains 95 per cent or over pure sulphate of ammonia, equal to 24.5 per cent ammonia or 20.2 per cent nitrogen. 5 parts of nitrate of soda are approximately equal in nitrogen to 4 parts of sulphate of ammonia.

Dried Blood.—Not so available as above, but a quick acting nitrogenous manure; contains 12 to 14 per cent nitrogen.

Horn, Shoddy, Wool-waste.—Insoluble, slowly available, nitrogenous materials. Horn contains about 14 per cent nitrogen, shoddy and wool-waste 4 to 12 per cent.

Guano.—Divided into nitrogenous and phosphatic guanos. Nitrogenous guanos contain from 5 to 10 per cent of nitrogen, much of which is rapidly available, from 20 to 35 per cent of phosphates, and 2 to 4 per cent of potash. They are derived from various sources and vary greatly in value. Phosphatic guanos contain less nitrogen and generally from 35 to 60 per cent phosphates. Not so available as nitrogenous guanos. Improved, equalised, and fortified guanos are mixtures of phosphatic guano with other materials, such as sulphate of ammonia and potash salts.

Fish Guano.—Also known as fish powder, fish manure, and fish meal. It is manure prepared from dried fish refuse. It varies greatly in composition. It usually contains nitrogen from about 6 to 12 per cent, and phosphates from about 9 to 27 per cent. It is a fairly active manure, but requires a little time for decomposition. Varieties which contain much oil, such as those derived from herring, act more slowly than those containing little oil, such as white-fish guano.

Flesh Manures.—These are derived from dried flesh. They sometimes get the name of guano. They contain variable proportions

of nitrogen and phosphate according to origin. In composition and value they resemble the fish guanos.

Bone-meal.—Contains on an average 50 per cent phosphates, and $3\frac{1}{4}$ to 4 per cent of nitrogen. These are insoluble and slow acting. Their activity depends on the fineness of their division.

Steamed Bone-flour.—Contains from 60 to 70 per cent of phosphates and from $\frac{3}{4}$ to $1\frac{1}{2}$ per cent of nitrogen. This material should be ground into very fine powder, and is then quicker in its action than bone-meal.

Dissolved Bones.—Generally contain from 12 to 22 per cent soluble phosphates and from 12 to 25 per cent of insoluble phosphates. When the soluble phosphates are high the insoluble are low, and *vice versa*. They contain from $2\frac{1}{4}$ to $2\frac{3}{4}$ per cent nitrogen, equal to $2\frac{1}{4}$ to $3\frac{1}{2}$ per cent ammonia. They should be prepared from bones and acid only. Though a valuable manure, and much esteemed by many farmers, it is one of the dearest per unit of nitrogen and phosphate.

Dissolved Bone Compounds.—These are really mixed manures prepared from dissolved mineral phosphates, and more or less valuable nitrogenous materials. A little undissolved bone also is frequently added. They vary much in composition, and have no right to the title dissolved bones, and dissolved bone prices should not be paid for them.

Superphosphates are made from ground mineral phosphates and acid. They contain from 26 to 40 per cent of soluble phosphate, and are valued solely for this constituent. The higher-grade superphosphates containing from 30 to 40 per cent soluble phosphates cost less per unit than low-grade superphosphates containing about 26 per cent. There is no reason why 26 per cent superphosphate should continue to be made, except that purchasers continue to demand it.

Mineral Phosphates, sometimes known as coprolites, are the cheapest but least available phosphatic manures. They contain from 40 to 80 per cent of phosphate, and should be ground to a very fine powder. Algerian or Tunis phosphates, which contain about 60 per cent phosphate, are now the most largely used, and appear to be rather more available than other kinds.

Basic Slag is also known as slag phosphate, Thomas' phosphate powder, &c. It contains from 20 to 40 per cent phosphate, of which at least nine-tenths should be soluble in dilute citric acid. It should be so finely ground that at least 80 per cent should pass a standard sieve with about 9600 meshes per square inch. In contrast to superphosphate, which is an acid manure, slag is an alkaline manure, and helps to neutralise any acidity of the soil.

Uncertain Character of Compound Manures.—Compound manures are so numerous and varied in their composition that it is impossible to indicate

those most suitable for any crop or soil. They usually contain phosphate, nitrogen, and potash in various proportions. But the purchaser must not only ascertain the percentage of these ingredients which may be present, but also the sources from which they are derived, and the form in which these are present.

Home Mixing preferable.—It is therefore considered more prudent for a farmer to buy a suitable combination of materials derived from known sources, such as bones, superphosphate, nitrate of soda, guano, &c., and make up the desired mixture for himself—that is, if he has taken the very necessary precaution of acquiring a knowledge of the characteristics of the different manures.

APPLICATION OF MANURES.

This is a subject which should receive careful consideration and timely attention from the farmer. Upon the manner in which this part of the work is done will, to a large extent, depend the success or the failure of the manurial treatment. Amongst the points to be considered are the character and composition of the soil, the nature and requirements of the crops, the rotation of crops pursued, the climate of the district in which the farm is situated, and the character and condition of the manure itself.

Application of Dung.

In the application of farmyard manure, simple as the matter may seem, there is great divergence of practice.

Turning Dung-heaps.—Differences of opinion exist as to whether or not it is necessary or desirable to “turn” dung-heaps before applying the manure to the land. This depends to some extent upon the manner in which the manure has been made and treated generally during the time it has been accumulating. Some believe that a certain amount of fermentation is necessary to prepare or “ripen” the dung. It is desirable that the dung should be as uniform in texture and character as possible. This may be ensured by turning. Rank, fresh, unevenly made dung, will therefore be improved by being turned over and well mixed a week or so before application.

Recent investigations point more strongly against the turning process, and many farmers and chemists regard it as both unnecessary and injurious. Mr Milne, Mains of Laithers, Aberdeenshire, looks upon the turning of ordinary dung-heaps as waste both of time and of ammoniacal matter. The more dung rots the denser it becomes, and therefore the more difficult to spread evenly on the land, while the unbroken lumps will the longer lie on the land in a useless condition. This, Mr Milne says, any one can verify after a dry summer. If the drills into which the dung had been put are split up, little or none of the fresh dung will be seen, while the rotten dung will turn up almost as solid as when applied. In his part of the country, Mr Milne has not seen a dung-heap turned for twenty years; and if artificial manure is to be used along with the dung, he considers turning quite unnecessary.

In so far as concerns the dung itself, there will, as a rule, be little necessity for turning, provided it has been properly made and taken care of in the cattle-court—that is, if the litter has been evenly distributed (or, better still, cut into short lengths), and well and regularly saturated with urine, so that the dung may come out moderately short and of uniform texture and quality. Indeed, with dung so made and treated, there are strong considerations in support of the contention of many farmers, that it is better to cart such dung right from its original position in the court to the land for distribution.

Carting out Dung.—In many parts of the country the dung is turned, not because the turning itself is considered necessary, but because it is deemed advisable, in order to facilitate work in the busy season of laying down roots, to have the dung carted into heaps on the field some time during the winter, when in these parts there is little other work which can be done by either the men or horses. In reference to this point, it is maintained by many that it would be impossible for farmers in many parts of the north to put in the turnip crop seasonably without another pair—in some instances perhaps two pairs—of horses, if the dung had all to be carted from the steading at this busy time of

the year. It is also pointed out that if rank fresh dung is once turned before application, it is easier to spread it on the land. This is unquestionably true, provided it is not allowed to become so rotten as to get into the dense lumps referred to by Mr Milne. Thus, while a certain amount of turning and fermentation facilitates the even spreading and speedy action of dung in the soil, excessive rotting may to some extent operate against both. It is certainly very important, in carting out or turning dung, that great care should be taken not to allow fermentation to go too far, as in that case a considerable portion of the valuable plant-food in the manure might be lost. Fermentation may be regulated by compressing the dung when it is too rapid, and by opening up the dung when it is too slow.

Process of Turning.—If a dung-heap in the field is to be turned, a beginning should be made at the end farthest from the head-ridge. The unturned dung-heap slopes a little at both ends, but the turned dunghill should be made of the same height throughout. A dunghill is turned over in a succession of breadths of 3 feet, which affords sufficient room for people to work in; but the first few breadths should be narrower than 3 feet, until the desired height of the turned dunghill is attained at that end. At the centre, the height is lowered to that of the first end, and the last end is heightened to the general level.

There is more of good management in attending to these particulars of turning a dunghill than is at first apparent. A turned dunghill will not putrefy equally when of different heights—the greatest heat will be at the highest part, where the dung will become short and compact, whilst at the shallowest it will continue comparatively crude and unprepared; and such different states of the manure will have different effects upon the crop. In ordinary practice, the uniform height of the dunghill is often miscalculated, and thus the ends still continue lower than the centre. The endeavour to equalise the height by throwing dung from the middle to the ends does mischief, inasmuch as no complete union takes place between the turned dung and that thrown upon it, the two portions

remaining in different states, and rising unequally to the graip when thrown into the cart. Besides, trampling the centre when the dung was thrown to the ends causes it to become harder than the rest of the heap, and so to undergo a different degree of putrefaction. In fact, the whole job is bungled.

Dung, properly speaking, does not ferment, but putrefies.

Intermixing.—The outside and drier portions of the dung are put into the inside of the dunghill, and, where different sorts of dung are met with, they are intermingled intimately. Each dace is cut off, and turned over from the top to the bottom. When the bottom is reached, the earth damped by the exudation from the dung-heap is shovelled up by the men with the square-mouthed shovel, or the frying-pan shovel, fig. 342, and thrown upon the breast of the turned dung.

When straw ropes are met with, they should be cut into small pieces and scattered amongst the dampest parts of the dung-heap. Though the dung-heap is cut into parallel trenches, the dung from the top of the new trench is not thrown down upon the bottom of the former one, like trenching land, but upon the breast of the turned dung, which slopes upwards away from the workers. The advantage of this arrangement is not only that the dung is thereby intimately intermixed and not in separate independent trenches, but that when the dung is being carted away it rises freely with the graip.

Fig. 343 represents an excellent steel graip, such as is used in filling dung, made by Spear & Jackson, Sheffield.

In finishing the dunghill, the men shovel up all loose dung and earth along its sides and ends to the top, and a dung-heap thus turned over forms a parallelopipedon, and is a good-looking piece of work.



Fig. 342. — Frying-pan or lime shovel.

Lime-shovel.—Fig. 342 is a frying-pan shovel, which is so named from its similarity to that culinary utensil. It is also called the lime-shovel, as being well adapted for the spreading of lime upon the land, the raised back protecting the hand from the lime, while the sharp point passes easily under it and makes its way along the bottom of the cart. This shovel is chiefly confined to the Border counties. It makes clean work at everything, and is easily handled.

Spreading Dung.—Whether on the flat or in drills, dung is still most largely spread with hand-forks or graips, but machines for spreading both broadcast and in drills are coming into use. A very good machine for spreading dung in drills, made by Allan & Sons, Dunkeld, is represented in fig. 344.

Turning and Putrefaction.—Unless much rain has fallen from the time the dung was led out of the court until the heap is turned, the

and mixing together, which should be quickly done, a heat will manifest itself in the course of a few days. The first putrefaction produces no great degree of heat, as the air is still cool at night, and the largest proportion of the heap consists of cattle-dung, which is slow of putrefaction.

Symptoms of Putrefaction.—The first external symptom of general putrefaction is subsidence in the bulk of the heap, which, in the course of 2 weeks, may contract 1 foot of height. A perceptible smell will then arise from the dung, accompanied with a flickering of the air over it, which is occasioned by the escape of vapour and of gases. By inserting a few sticks into the heap here and there, a heat considerably above that of the hand will be felt, and the relative heat of different parts ascertained; and the greatest heat may be expected at the side opposite from whence the wind comes. The actual degrees of heat may be ascertained by the dung-thermometer.

The substance of the dunghill consolidates uniformly, and a black-coloured liquid oozes out at the ground. If the soil upon which the dunghill stands is soft, the oozing is absorbed by it; but if firm, the moisture remains on the surface, and forms small pools in the ruts of the cart-wheels or open furrows. The leakage is trifling; and much moisture cannot exude from dung derived from courts in which the cattle are supplied with as much litter as keeps them dry and warm.

In former times dung intended for turnips was often turned twice, but the losses by excessive fermentation are now better understood than formerly, and farmers are therefore more careful in the treatment of their dung.

Turning Court Dung.—For potatoes, particularly well-made court dung, which has perhaps been made under roof, and is concentrated rather than rank, is considered by many to give the best results when taken direct from the court without previous turning and applied to the soil. Turning is by most farmers regarded as more necessary for turnips than for potatoes. The ripen-



Fig. 343.—Steel graip.

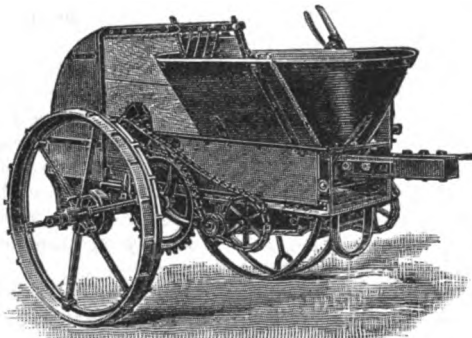


Fig. 344.—Allan's drill dung-spreader.

dung will not be very moist, and not at all wet, but in a good workable state, with a slight degree of heat in it.

After this turning over, shaking up,

the dung—that is, if the rotten dung is thoroughly broken and evenly spread on the land—the earlier does it begin to afford nourishment to the plant, which, with the young turnips, is a matter of special importance.

Less Necessity for Turning.—Turning, as we have seen, is pursued chiefly to promote the rotting of the dung. One of the main objects of having the dung well ripened or rotted is to facilitate its speedy action after application to the soil. Formerly, before the introduction of more quickly acting manures, there was great necessity for this, as otherwise, on account of the slow decomposition of fresh dung, the crops would be liable to suffer from scarcity of available food in their earlier stages. Now, however, the crops can be efficiently nourished in their youth by highly soluble artificial manures, which are fit for assimilation by the crop as soon as they are applied. Thus more time can be afforded to the dung for decomposition in the soil, so that there is less necessity for its prior ripening—less necessity for turning, thereby saving labour and lessening the risk of loss by excessive fermentation.

Time of Application.—The best time for applying farmyard manure will depend upon a variety of circumstances. Chief amongst these are the character of the soil, the climate of the district, and the crop to be grown.

On very strong land in preparation for a root crop, the autumn may be the best time. The dung will thus have more time to exercise its beneficial mechanical influence upon the soil, while summer tillage, which would be detrimental to such land, is avoided. But there is one great obstacle to this practice. Dung cannot be applied until it is made, and the main portion of dung is made during the winter months. Thus autumn manuring is impracticable, except where stock are fed in the house in summer, or where there is on hand a reserve supply of manure.

Southern Practice without Drills.—In many parts, especially in England, the system is as follows: Assuming that the stubble is clean, such manure as exists is carted from the yards after harvest, spread on the land, and turned

in with a moderately deep furrow. The land remains without further disturbance throughout the winter. As the root-sowing season approaches, the land is scuffed and harrowed, care being taken not to bring any of the crude soil to the surface. The chief desideratum on such soils, and the great secret of success, is to maintain a finely pulverised seed-bed. The mangel or turnip seeds are in this case sown in rows on the flat surface. In this way the moisture is retained, which is an important consideration under the more arid climate of the south. By careful attention to these details, a braird is almost invariably secured.

With Drills or Ridges.—If the land is to be ridged for the roots, then a somewhat different course must necessarily be pursued. The stubble is broken up by a deep furrow early in autumn. As soon as the land has become mellowed by the rains and frost, the soil is ridged up in the rough. Then when the land becomes sufficiently dry, or should a frost set in, the farmyard manure is carried and spread in the ridges which are split, and the manure covered in at the earliest opportunity. The land remains in this state until the season for sowing arrives. Advantage must then be taken of the first favourable state of the land, when a chain harrow is passed lengthways over the ridges. This has the effect of further pulverising the surface, already reduced by the action of the atmosphere.

Supplemental Manure.—If artificial manures are used along with the dung, now is the time to apply them, sown in the drill or broadcast over the surface. A double mould-board plough is then passed between the ridges, and the fine soil set up and the seeds sown. Great care must be taken not to bring any of the solid soil to the surface. Here the young seeds find a congenial soil in which to vegetate, and a supply of moisture within available distance.

Dunging Light Soils.—The once popular system of autumn manuring on light soils is now discontinued by the best and more intelligent class of farmers. The very process of deeply stirring such soils in the autumn in warm climates is a source of much waste. Tillage stimulates nitrification, and the rain-water passing through the soil washes out

nitrites, whether in the soil or in the manure, or both. In the south, where the winter is so mild that there may not be sufficient cold to check nitrification, such soils are usually more fertile when broken up in spring.

Northern Practice.—In the northern and colder counties different systems of tillage and manuring are pursued. Here the winter tillage of land for roots is universally pursued, so that the full benefit of the pulverising influence of the winter frosts may be secured. And this is done in these northern parts without incurring any serious loss of nitrites in drainage-water, as the winters are too cold to permit nitrification to proceed. Thus the general plan in the north is to plough land for roots with a deep furrow in the autumn or early in winter, let it lie bare till spring, then cross-plough it, and apply the dung in summer just before the seed is sown, the dung being usually spread in drills. This is the usual practice in Ireland also.

Dung for Wheat.—For wheat, the dung is either spread in the autumn, and at once ploughed in, or it is spread over the young plant during dry or frosty weather. The late Mr Gilbert Murray believed the best results were obtained by the latter method of application.

Dung for Grass Lands.—In top-dressing grass or meadow land with dung, the general practice is to apply the dung in the autumn. Little or no loss arises through its exposure on the surface.

Surface-manuring.—It is a mistake to bury dung deeply in the soil. Indeed it is now well known that nitrification proceeds in inverse ratio to the depth at which the manure is buried; hence the best results are obtained from farmyard manure when kept near the surface. This system of surface-manuring also benefits the layers of grasses and clovers as well as the young wheat. The alleged waste by exposure to atmospheric influences is now regarded as a popular error.

The late Mr Gilbert Murray stated that he farmed side by side with men occupying good turnip land, whose practice was to draw out and spread the manure on the prepared land, and turn it in with a shallow furrow. The roller closely followed the plough. Their usual sowing time was the last week in June.

The land, having lain three or four weeks, was scuffed, harrowed, and rolled, and the seed drilled 20 inches wide on the flat. A considerable portion of the manure was brought to the surface, yet he said he had considerable difficulty in growing a heavier weight of roots per acre on his 27-inch ridges with the manure carefully covered.

Quantities of Dung per Acre.—The old practice of applying excessive quantities of dung at one time has been shown to be wasteful. On an average of years better results will be obtained by a moderate quantity of farmyard manure, supplemented by a good selection of artificial manures.

So much depends upon soil, system of cropping, and quality of the dung, that to attempt to give definite directions as to what quantities should be applied for each crop might be more misleading than useful. From 8 to 12 tons per acre for roots, and from 15 to 20 tons for potatoes, are general dressings, along with artificial manures, which may cost from 25s. to 60s. per acre additional. In certain cases the allowance of dung would be less, and in other instances more.

Dunging Often and Lightly.—As a rule it is the best plan to dung often, and in moderate quantity at each time. As to this point, the late Mr Gilbert Murray wrote: "If the land is worked on the six course, I should divide the farmyard manure into three portions. One I should apply to the root break, supplemented by artificials; a second would be spread on the young seeds immediately after the separation of the crop; and the third I should apply to the wheat stubble on the separation of that crop and in preparation for the next cereal. I have long been convinced of the folly of applying the whole of the fold-yard manure to the root crop. Repeated doses at short intervals is the most effective system of applying dung."

Economical Use of Dung.—It seems to be well established that dung may be, as a rule, most economically used in moderate dressings, along with judicious mixtures of more quickly acting chemical manures.

Application of Artificial Manures.

There is assuredly ample scope for good or bad management in the appli-

cation of artificial manures. By the use of these manures all the elements of plant-food may be supplied either together or separately, or as many of them given and as many withheld as may be considered desirable. The subject is therefore one of vast importance, placing in the hands of the skilful farmer far greater possibilities than were within his reach when farmyard dung was the only available manure.

It is especially necessary in the use of artificial manures, that the farmer should most carefully consider the character and composition of the soil, the nature and requirements of the crops, the rotation pursued, the climate of the district in which the farm is situated, and the character of the manure itself.

Elements Absorbed by Crops.—In the first place, it would be well to have in view the amounts of the various ingredients abstracted from the soil and atmosphere for building up the substance of the crops. These have already been shown—see pp. 326 and 448.

These substances are present in soils in various proportions, the quantity of each being dependent on the origin of the soil in the first instance; and secondly, on the prior growth of plants on its surface—the residue left by the decay of these having a considerable influence on the natural fertility of every soil. The majority of these constituents exist in all soils in excess of the quantities required to build up the substance of crops, no matter what system of cropping may be pursued; and therefore the farmer, in order to render his soil fertile, has to supply only those few elements which are deficient in the soil.

Elements to be Supplied in Manures.—The subject of manuring is thus reduced to the supply of an *uncertain deficiency* of one or more of the following substances—viz, nitrogen, phosphoric acid, lime, and potash.

The form, manner, time, and quantity in which these substances are to be applied will manifestly depend on the preceding considerations enumerated in the first paragraph under the above heading—considerations which we shall now examine in detail.

Character of Soil and Manuring.—The character of a soil depends on the

proportion in which its proximate constituents, sand, clay, lime, or humus, may be present. If either of these preponderate, then the product is known as a clay, sandy, calcareous, or loam soil. These have all different textures, and consequently vary in their capability of retaining the more soluble manures. Sandy and open porous loams have less power of holding manure than clays or heavy loams. Then the relative fertility of all soils is regulated by the character and composition of the materials of which the soil is made up, whether this material owes its origin to the disintegration of the rock it overlies or is transported.

A Knowledge of Geology useful.—There are few studies that would give better paying results to the farmer than that of geology, as a knowledge of the character of the soils on the various rock-formations would correct many a blunder which occurs when a farmer changes to a new locality. Farm practice must always be modified by the relation of the soil to the underlying strata, and not only this, but the system of manuring must also in so far be regulated by the same considerations.

Manures for Different Soils.—The surface-soil and the general practice as to the application of manures may now be considered. On clay soils the best results are usually obtained from nitrogenous and phosphatic manures—the former having the greater influence; on loams, from phosphatic and nitrogenous manures—the former exercising the greater power; while on sandy soils a combination of nitrogenous, phosphatic, and potassic manures generally gives the best return. Soils intermediate between either of these groups will give results in proportion to the modification of the mixture of manures.

Form of Application for Different Soils.—Then, again, the form in which the manure is applied must depend on the composition of the soil. A sandy soil cannot retain a soluble manure: for it, therefore, it is safest to give nitrogen in the form of fish guano, guano, or other organic matter; phosphates, as bone-meal or slag; and potash, as kainit. Loamy soil will usually give the most satisfactory results from nitrogen in the form

of sulphate of ammonia and nitrate of soda mixed, and one of bones to two of superphosphate; whilst clay will respond most freely to nitrate of soda, and superphosphate, three parts—one of bones and two of slag.

Evidence of the Soil.—But the only evidence which is absolutely reliable as to the immediate manurial wants of a soil is that of the soil itself, as expressed, not in chemical analysis, but in various crops carefully arranged so as to test the available supplies of the different elements of plant-food contained in the land. As to how this evidence may be procured, refer to Ville's remarks on pp. 450, 451, and to "Farmers' Experiments" on p. 452.

Tillage and Manuring.—In applying artificial manures, it should be borne in mind that the natural source of plant-food is the soil, and that manure is merely supplemental. The farmer should therefore, by careful cultivation, endeavour to prepare these soil ingredients so as to render them available to the plant. The quantity of manure required may thus be, to a considerable extent, influenced by the care bestowed on the tillage operations. With efficient and timely cultivation, a certain amount of manure will produce better crops than would be obtained from twice as much manure with bad, ill-timed tillage. One of the most noteworthy facts demonstrated in the Rothamsted experiments is the great influence which perfect tillage and the keeping down of weeds exercise on the productive power of a soil. Indeed, the application of manures cannot possibly be profitable to the farmer unless the soil be moderately well cultivated, as well as efficiently drained.

Return of Manure on Exhausted Land.—It is often remarked by practical farmers that no soil responds more freely to the application of artificial manure than one which had been previously neglected and partially exhausted. The cause of this is obvious. By the repeated cropping without receiving an adequate return in the shape of manure, this soil becomes exhausted of certain of the elements of fertility, while by the decay of the roots of the crops other elements of plant-food are stored up in increasing quantity. Then, when the neglected land is well tilled and the deficient

elements supplied in a suitable manure, the store of fertility is called into action, and the result is a bountiful crop.

Manures for Different Crops.—The form and quantity of manure must be carefully adapted to the requirements of the crop.

Limited Guidance of Experiments.—Many experiments have been carried out for the purpose of determining the best form, kind, and quantity of various fertilisers for the different farm crops; but, as has already been stated, the local circumstances of soil and climate and the customs of farming vary so greatly that the results and lessons of these experiments are not, as a rule, to be relied on as guides beyond the respective districts and conditions in which they have been conducted. The results obtained at Rothamsted, and other places, have most certainly been of great benefit to the agriculture of this country, yet it is well to bear in mind that the circumstances under which these have been carried out differ substantially from the conditions surrounding ordinary rotation farming such as prevails throughout the country. It is thus obvious that farmers cannot with safety resort to these experiments for specific directions as to the manuring of their land.

Value and Uses of Experiments.—At the same time, with a full knowledge and intelligent conception of his own local surroundings—of the character and condition of the soil, the requirements of the crops to be grown, and the climate of the district—the farmer may unquestionably derive valuable aid in his practice of manuring by careful study of such experiments as have been carried on at Rothamsted, and at many other places throughout the country.

Manures for Slow- and Fast-growing Crops.—It is important in the practice of manuring that the habit of growth of the different crops should be carefully considered. A slow-growing crop, for instance, should receive different manurial treatment from that which is best adapted to fast-growing crops. A slow-growing crop requires a mixed manure, partly soluble, and the balance coming slowly into action. Wheat, which occupies the ground for a comparatively long period, will, as a rule, be able to

obtain from the soil all its mineral ingredients, and therefore a supply of readily available nitrogen seems to be all that is required. Barley, on the other hand, is a plant of more rapid growth, and being shallow-rooted, must have its food ready, and near the surface, to ensure a large produce. Then, the leaf-surface is also important, for a plant is dependent on the soil or the atmosphere for its increase in proportion to the extent of its foliage.

Soil, Climate, and Manuring.—But a still more important consideration is the bearing of soil and climate upon the weight of the crop. For example, in a dry climate 12 to 15 tons is a very general yield of roots; while in a moist climate and favourable soil the produce per acre will be nearly 30 tons, often indeed as much as 40 tons. Now it would be manifestly absurd to apply the same quantity of manure in these two cases. To the consideration involved here is due the diversity and misunderstanding which frequently arises as to the practice of manuring. About 3 cwt. of superphosphate per acre is usually found a suitable quantity to allow for roots in the south of England, where the yield is generally under 20 tons per acre; but in the north of Scotland, where much heavier crops of roots are grown, this quantity may be increased, with economical results, to at least 5 cwt. per acre, besides, perhaps, some bones and nitrogenous manure.

Rainfall and Artificial Manures.—And the climate, particularly the rainfall, should also influence the form in which a manure is to be applied. Every farmer must have noticed that in a dry season the effect produced by artificial manures is very slight indeed, the more soluble showing better results than insoluble manures. From this it may be concluded that soluble manures are most suitable for a dry climate, whilst the less readily available kinds will give better results over a rotation of crops in a moist one.

These remarks are fully borne out by the practice pursued in different localities. In the north and east, where the climate is moderately moist, the application of artificial manure may be about 5 to 6 cwt. per acre; while in the west

and south-west, where the climate is wet, the dressing may rise to 7 or 8 cwt. per acre—3 to 4 cwt. being usual quantities in the dry climate of the south of England.

Manures for Different Rotations.—The length of the rotation must also be considered in determining the form of manure to be applied. For instance, three years' grass will necessitate a larger application of phosphates in the form of bone-meal or slag. For long rotations the slow-acting manures are employed.

More Frequent Manuring.—But many farmers now consider that it is a mistake to apply to the turnip or other green crop the entire quantity of manure required for a rotation of crops. When one considers the solubility of most of the artificial manures now in use, one can readily understand that the spreading of the manure over the crops of the rotation would result in less loss of fertilising matter, and lead to a more reliable increase of crops on an average of years. The advantages of this system of manuring have been well shown by the results of extensive and well-arranged experiments conducted at Kilmarnock by the West of Scotland Agricultural College. These trials gave much better results where each crop was manured for its own wants with quick-acting manures, than where practically all the manure for the rotation was applied with the root crop.

These considerations would lead the farmer to infer that a moderate dose of soluble phosphates, applied along with the seed, would be most suitable for green crops; and if nitrogenous manure were considered necessary, then sulphate of ammonia or nitrate of soda could be given with the seed or after singling, or guano might be applied at the time of sowing.

Grass seeds then might receive an application of soluble and insoluble phosphates, along with nitrogenous manure—the mixture being varied according to the intended duration of the grass, whether two, three, four, or more years. Then, again, the corn crops after lea would require another top-dressing of phosphates and nitrate of soda. This method would be specially suitable in

a climate subject to heavy rainfall, while as a rule it would be safe and economical for average conditions in this country.

Ratio of Different Ingredients.—On account of the diversity of conditions and influences which have been noticed, it is considered unsafe to attempt to prescribe definite doses of manure. But it may be stated approximately that the *ratio* of the manurial elements for green crops with dung should be about 4 of phosphoric acid to 1 of potash; for oats and barley, 2 of phosphoric acid to 1 of nitrogen; for wheat, 2 of nitrogen to 1 of phosphoric acid; and for grass, 1 of nitrogen to 2 of phosphates and 1 of potash.

Time of Application.—Until recently, artificial manures were generally applied along with the seed. Slow-acting nitrogenous manures may be thus applied, but nitrate of soda, as a rule, gives the best results when not sown till after the braird appears. When a heavy dressing of nitrate of soda is to be given, one-half the quantity should be sown then, and the balance held over for later application.

Nitrate of Soda is the most quickly acting of all nitrogenous manures, and is therefore the best adapted for a late dressing to push on a dragging crop. But in a late wet climate, or rainy season, it may not be advisable to apply nitrate of soda, for it has a tendency to force up a rank growth of straw, thus perhaps making the harvest too late, and so endangering the yield of grain.

Sulphate of Ammonia would be more suitable in these circumstances. Indeed, as a rule, in wet districts or very rainy seasons, sulphate of ammonia gives better results than nitrate of soda. In dry seasons, and on dry soils, exactly the reverse is usually the case. But sulphate of ammonia is not nearly so well suited for top-dressing as nitrate of soda. A safe method of applying sulphate of ammonia is to mix it with dry fine soil (not ashes, as these might cause loss of ammonia), sow broadcast, and plough in immediately.

Mr Warrington remarked that *top-dressing* with nitrogenous manures is especially to be avoided when the soil contains any considerable amount of lime, as loss of ammonia might then occur.

Phosphates may be sown any time during winter or early spring. The wisdom of the old practice of sowing in the drill was questioned a number of years ago; but recent experiments have shown that phosphates, such as superphosphates and basic slag, give the best results when applied in the drill for green crops.

Sowing Manure in Drills.—In sowing artificial manures in the drills the following plan is found to work well, the manure, as we have already seen, being conveyed to the land in carts: The loads ought each to contain 20 bushels, and thus in, say, a 20-acre field 8 loads are to be applied. The width of the field is, say, 240 yards, and we divide it into breadths of 60 yards. Two carts full of manure are unloosed in each breadth; and the sowers, one to each drill-plough, are started with a weighed quantity to sow along the drill so many yards. If the drills are 27 inches wide, then to sow 6 cwt. per acre, 21 lb. will sow one drill 200 yards. After the sower ascertains the quantity to take in the hand to effect this, he will have no difficulty in applying the quantity correctly, and he will always have a check when each pair of carts are emptied.

The reason for having the carts in pairs is to save the carrying of manure long distances. The sower can load-up himself, as the space he will thus have to travel will not be too great. In a field, say, 20 chains long, the carts will be placed, one 5 chains from the top, the other 5 chains from the bottom, about 20 yards away from the face on the prepared land, not in the drills.

Another Method.—Another method, still more precise, is conducted as follows: The manure, which is riddled just before being used, so that there may not be any lumps to interfere with even distribution, is sown with a machine, which does three drills at once. The length of the drills is measured to ascertain the number required for an acre. The quantity for each drill is calculated, and the quantity necessary to sow three drills put into one of the artificial manure bags and weighed on a weighing-machine. A bag for each three drills is laid down at each end of the field, making it very convenient to put

into the machine without loss of time, and each three drills in this way get their own exact quantity of manure. The weighing of the bags takes up very little time. They are filled to sight as near the quantity as can be guessed, then lifted on to the machine and adjusted to the required quantity according to the rate per acre.

This system may be considered unnecessarily precise, but the result on the crops has proved that it is worth more than the additional labour, which indeed is very little when properly conducted.

Sowing Manures by Machines.—The practice of sowing artificial manures by machine is much preferable to sowing by hand, and it is fast coming into

favour. By an efficient machine a more even distribution can be secured, and the importance of this is not easily overestimated. Careful consideration cer-

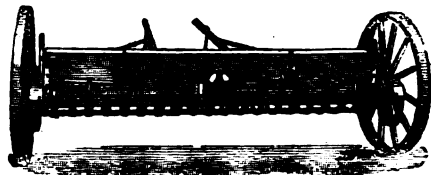


Fig. 345.—Broadcast manure-distributor.

tainly shows it to be greater than most farmers seem inclined to regard it. Unless the manure is evenly distributed, its full benefit cannot be obtained, and to

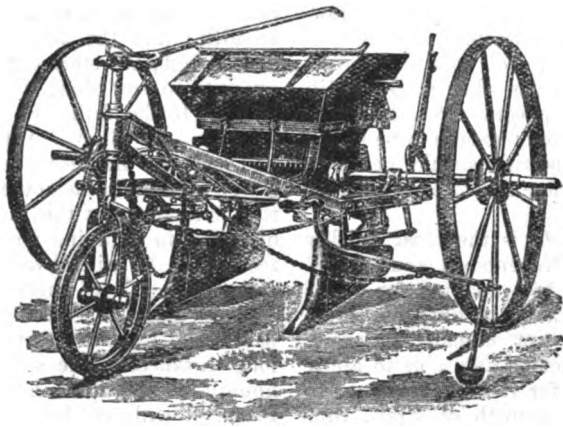


Fig. 346.—Double drill plough and manure-distributor.

secure this, the cost of an efficient manure-distributor would be a good investment. A good broadcast manure-distributor, made by Ben. Reid & Co., Aberdeen, is represented in fig. 345. A very useful contrivance, which at one operation

opens two drills and sows artificial manure in them, is shown in fig. 346. It is made by Jack & Sons, Maybole.

The well-known hand-sower "Little Wonder" is also well adapted for sowing dry manures.

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